1982

SQUAM LAKE ASSOCIATION

SQUAM LAKE AND LITTLE SQUAM LAKE

LAKE LAY MONITORING PROGRAM

1982

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

Coauthored by

A. L. Baker J. F. Haney

To obtain more information about the LLMP (Lake Lay Monitoring Program) please contact Dr. Baker at (603)-862-2060 or Dr. Haney at (603)-862-2100.

+

PREFACE

A non-technical, comprehensive summary concludes the report. The summary is intended to provide a quick reference to the main findings of the study. The reader is referred to Appendix A for a summary of Lay Monitor data for 1982, and to Appendix B for a clarification of technical terms and concepts.

ACKNOWLEDGEMENTS

The 1982 LLMP program at Squam Lake and Little Squam Lake was discussed during April in Concord, between representatives of the Squam Lake Association, (SLA) including W. Richardson Blair, Dr. R. F. DeWitt, and Benjamin Kimball Ayers, and representatives of the Freshwater Biology Group (FBG) -- Drs. Baker and Haney. Agreement to continue the LLMP program initiated in 1979 and 1980 was reached, and a Memorandum of Agreement was signed.

Because of the excellent organization of the SLA, the LLMP program has been very successful again in 1982. Data required to describe the 1982 trophic status of the lakes have been collected, sent to the FBG in Durham, and processed. Three (1980 - 1982) of the four years of data are now on computer files, and can be made available in raw form, or in statistical or graphic form when needed by the SLA. The 1979 data (first year of monitoring) will be added to the computer files as soon as possible.

As in previous years, the program continued successfully to a large extent through the efforts and enthusiasm of lay monitors.

Many people were involved as lay monitors during 1982, most of whom have also been involved in previous years:

Little Squam Lake (site 1) --

Dr. R. F. Dewitt and Dr. L. B. Copenhaver.

Squam Lake, Sturtevant Bay (site 2) --

W. G. Elliot.

Squam Lake, Livermore Cove (site 5) --

John C. Hurd, Broadhurst and Poulos.

Squam Lake, Rattlesnake Cove (site 8) --

Daphne M. Mowatt, D. L. and E. T. Brooks.

Squam Lake, Squaw Cove (Sites 9A and 9B) --

D. L. and E. T. Brooks, R. Abel and Butterworth.

Squam Lake, Sandwich Bay (site 10) --

Sally Biddle.

Squam Lake, Kent Island (site 11) --

Arthur Greenfield.

Squam Lake, Bean Cove (site 13) --

R. I. Butterfield, Jr.

Squam Lake, Sturtevant Bay (site 14) --

Allan Miller and Seery.

Squam Lake, Center Harbor Neck Bay (site 15) --

Richard Cabell.

Squam Lake, Dog Cove N. of Mouse Island (site 16) --

A. and Jean Whatley.

Squam Lake, Hodges Cove (site 17) --

Preston R. Smith.

Squam Lake, Piper Cove (site 18) --

Daphne M. Mcwatt

In addition, we wish to thank all other members of the Squam Lake Association who shared in the financial support of the LLMP program during 1982.

We wish to thank the SLA for providing boats for our field team. The field trips were very successful, thus we have a third complete year of fine field data.

Members of our Freshwater Biology Group field team included Kim Babbitt, Dan Hayes, Tim Lorette and Martha Salvato. Everyone pitched in to help construct the sampling kits at the beginning of the season. Responsibility for field analyses was shared by all members of the field team. In Durham, Tim was responsible for phosphorus analyses, Kim for chlorophyll a analyses, Martha for phytoplankton analyses and Dan for Zooplankton analyses (getting help from Kim). In addition, Martha was responsible for organizing field trips and collating data. Dan was responsible for maintaining our cumulative computer files of all data. In addition, Dan and Kim contributed portions of the Methods

section and portions of Appendix B.

This report has been produced in large part with data management and word processing programs on the UNH DEC-10 computer. Graphics were produced with program UPLOT and the CALCCMP drum plotter available on the DEC-10 system. The Office of Computer Services kindly provided computer time and data storage space for the ILMP.

TABLE OF CONTENTS

INTRODUCTION

This report presents the findings of the 1982 summer study of Little Squam and Squam Lake in Holderness, New Hampshire. The study was conducted by the Squam Lake Association and the Freshwater Biology Group (FBG: Baker, Haney and students), University of New Hampshire, as part of the Lake Lay Monitoring Program (LLMP). The LLMP is a long-term water quality monitoring program that relies heavily on lay persons, generally members of lakeshore protection associations. The inception of the program in October 1979 was during a meeting of member of the Squam Lake Association and freshwater biologists at Durham.

The LLMP involves a cooperative effort between the Freshwater Biology Group (FBG) at U.N.H., and participating lake associations, conservation commissions, and municipalities. It is directed by Doctors Alan L. Baker (Associate Professor, Dept. of Botany) and James F. Haney (Associate Professor, Dept. of Zoology). Space and research facilities were provided by the Botany and Zoology Departments. Some secretarial services were provided by the Water Resources Research Center.

At Durham the LLMP is conducted by Drs. Baker and Haney, and a research team of trained graduate and undergraduate students. The student team has a leader or field coordinator, and specialists for various analytical procedures. Funding for the LLMP is provided by the participating organizations, including in 1982 the Hudson Conservation Commission, the Lake Winona Association, the Lovell Lake Association, Merrymeeting Lake Association, Lake Winnipesaukee Association, the Squam Lake Association, the Town of Salem, and the Walker Pond Protection Association.

During 1982, the third year of monitoring on Little Squam and Squam Lake, the independent study of lake physics, chemistry and biology was continued by the FBG field team from Durham. The FBG study provided additional baseline data as well as served as a "quality control" check on the results of the lay monitors.

As in previous years a computerized data base has been maintained, incremented with each new observation. The cumulative data base will be essential both now and in the future as the source for assessing any changes (either for the better or for the worse, or none at all) in water quality. All data collected by the lay monitors are considered to belong jointly to the respective monitors (and the group represented), and the Freshwater Biology Group.

Other goals of the LLMP are not as immediate and require a long-term commitment from the participants. Through continuous long-term lake monitoring, declines in water quality can be detected early and appropriate action taken before further lake degradation occurs. At the same time, if appropriate measures are applied in an attempt to reverse the degradation, improvements can be observed through the data base, to allow an assessment of the value of the management program conducted.

Equally important as a result of the LLMP is the educational experience that the LLMP provides for all involved. Increased public awareness of lake ecology and water quality conservation is an attribute of the LLMP that should foster the development of sound lake management policies in the future.

Results from both the lay monitors and the Freshwater Biology Group (FBG) are included in this report.

METHODS OF LAY MONITORS

Lay monitors collected data on three parameters: thermal stratification, water clarity, and chlorophyll a concentration. Data were collected at approximately weekly intervals.

Data on thermal stratification were collected with a modified Meyer bottle (Lind,1979). Samples were obtained by lowering the empty but weighted bottle and sampling (by pulling out the stopper) at 1-meter intervals. The temperature of the samples was taken with Taylor pocket thermometers.

Water clarity was measured while lowering an 8-inch (20 cm) Secchi disk and holding a view-scope just below the surface to eliminate the effects of surface reflection and wave-action. When the Secchi Disk disappeared the depth mark on the plastic suspension line was noted. The disk was raised until it just came into sight, and again the depth on the line was noted. The process was repeated two to three times, and an average between the two marks on the line (the point of disappearance and the point of re-appearance) was considered to be the Secchi Disk Depth (SDD), measured to the nearest one-tenth meter (0.1 meter) -- as for example, 5.2 meters. Readings were generally taken between 9 a.m. and 3 p.m., the period of maximum light penetration.

Chlorophyll a concentration was used as an estimator of algal biomass. A weighted tube 33 feet (10 meters) in length was used to collect an integrated water sample from the 'upper-lake' (epilimnion). The weighted end of the tube was slowly lowered to the interface of the epilimnion and the 'middle-lake' (metalimnion). The end of the tube was then bent double to shut off flow of air and water, and the weighted end of the tube (presently at the base of the epilimnion) was pulled up to the surface with a plastic line attached to it. The water in the tube (epilimnetic lakewater sample) was poured into a plastic bottle by placing the weighted end of the tube into the neck of the bottle and, while keeping the bent-off end above the weighted end, unbending the upper end (allowing the sample to discharge into the bottle).

Water samples were filtered through a membrane filter with a porosity of 0.45 microns. The damp filters containing chlorophyll-bearing algae were air dried for at least 15 minutes to prevent decomposition. Filtration and drying were done in the shade to minimize destruction (by bleaching) of chlorophyll. The dried filters were then sent to UNH for analysis. [In Durham, members of the Freshwater Biology Group extracted chlorophyll in 90% acetone saturated with magnesium carbonate, and read the absorbance of the sample at standard wavelengths (663 and 750 nanometers). If sufficient pigment was present, the sample was acidified and reread to enable estimation of the percentage of active chlorophyll relative to the sum of the pigment plus all of its breakdown products that were present.]

METHODS OF FRESHWATER BIOLOGY GROUP (FBG) TEAM

The same as well as additional parameters were investigated by the FBG research team. The additional factors were primarily measurements of sunlight penetration into the lakewater, and water chemistry. The latter included dissolved oxygen, 'free' (unbound) carbon dioxide, pH, specific conductivity, and total phosphorus. In addition, the microscopic plants (phytoplanktonic algae) and animals (zooplanktonic invertebrates) were identified. Relative or absolute counts were made.

Dissolved oxygen and temperature were measured with a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at 1-meter intervals throughout the 'upper-lake' (epilimnion) and 'lower-lake' (hypolimnion), and at half-meter intervals through the 'middle-lake' (metalimnion).

Sun- and skylight penetration into the lakewater was measured at 1-meter intervals with a Li-cor model LI-185A Quantum/Radiometer/Photometer, and photon-flux density was recorded. Measurements were taken on the sunny side of the boat.

Water chemistry (dissolved oxygen, alkalinity, free carbon dioxide, pH, and specific conductivity) samples were collected with a 3-liter Van Dorn bottle. Samples to be analyzed for alkalinity, free carbon dioxide, specific conductivity, and pH were stored on ice in 250 ml polyethylene bottles. Dissolved oxygen samples were fixed with the first two 'Winkler reagents' (manganous sulphate and alkaline iodide azide) in 300 ml Biological Oxygen Demand (BOD) bottles and kept on ice and in the dark.

Alkalinity, free carbon dioxide and pH were determined in the field, within 1 to 2 hours of sampling.

Dissolved oxygen was determined with the alkaline-iodide-azide modification of the Winkler method (E.P.A., 1979). Samples were titrated with .025 N phenyl arsine oxide (Hach Co.), with disappearance of the blue starch-iodine complex as the end-point indicator.

Alkalinity was determined titrimetrically with 0.02 N sulfuric acid to a final pH of 4.5, with a combination solution of the two dyes bromocresol green and methyl red as the end-point indicator (E.P.A.,1979). Alkalinity is expressed as equivalents of calcium carbonate.

'Free' (unbound) carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N NaOH to a final pH of 8.3, and with the dye phenolphthalein as the end-point indicator.

pH was measured with a Corning Model 10 pH meter equipped with an Orion combination probe.

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB equipped with model B-10 probe (cell constant = 1.0). Correction for sample temperature was made with a standard curve.

Samples to be analyzed for total phosphorus, phytoplankton, and chlorophyll a were collected with the tube sampler. Chlorophyll a samples were filtered, dried and analysed in the same manner as those collected by lay monitors.

Total phosphorus samples were stored in acid-washed 250 ml polyethylene bottles, and were fixed within 1 to 2 hours with 0.5 ml concentrated sulfuric acid. In their Durham laboratory the FBG members digested the total-phosphorus in the samples to reactive ortho-phosphate by boiling a 50 cc subsample nearly to dryness (several hours). Afterward the sample volume was reconstituted with the addition of double-distilled and deionized water. Finally, the phosphorus content of the samples was analyzed with the single-reagent method that included a fresh solution of ascorbic acid and potassium antimony tartrate (E.P.A., 1979). Absorbance of the blue phosphorus complex was measured spectrophotometrically at 650 nm.

Phytoplankton samples were fixed with iodine (Lugol's Solution) in the field, within 1 to 2 hours after collection. Phytoplankton were counted with a Wild 'inverted' microscope after settling the samples for 24 hours in counting chambers. At least 200 individual algal 'units' were counted with a modified scan technique (Baker, personal communication).

Zooplankton density was estimated in samples collected by towing up a plankton net (30 cm diameter, 150 micron porosity) through the epilimnion. Samples were fixed after collection with a 4% formalin-sucrose solution (Haney and Hall, 1973), and subsampled with a 1-ml Hensen-Stemple pipet. Sufficient subsamples were taken to insure that at least 100 microcrustaceans were counted.

RESULTS AND DISCUSSION OF LAY MONITOR DATA

Lay monitor research was conducted separately from the Freshwater Biology Group research, and thus the results are also presented separately. Sample site 1 in the deepest area of Little Squam was monitored in 1982. All sites previously monitored in Squam Lake were continued during 1981 (Fig. 1). Site 12 (Moultonboro Bay) was added. Lay Monitoring data collected in the two lakes during the summer of 1982 are summarized in Appendix A.

Secchi Disk Transparency and Chlorophyll a

The transparency of lakewater is dependent on two factors -- the total amount of suspended particulate material in water, and the total dissolved coloring matter in the water. The suspended particulates generally include microscopic algae and bacteria, along with microscopic animals. In addition, non-living particles such as wind-blown dust, stream-carried sediments, and resuspended lake sediments may find their way into the water column. In extreme cases the water in lakes may be very cloudy or turbid due primarily to the non-living particulates (lakes at the snouts of glaciers, or lakes receiving a large load of suspended silt from large rivers or from sewage systems). Normally, however, New Hampshire lakes become turbid as a result of the microscopic life present in the water column.

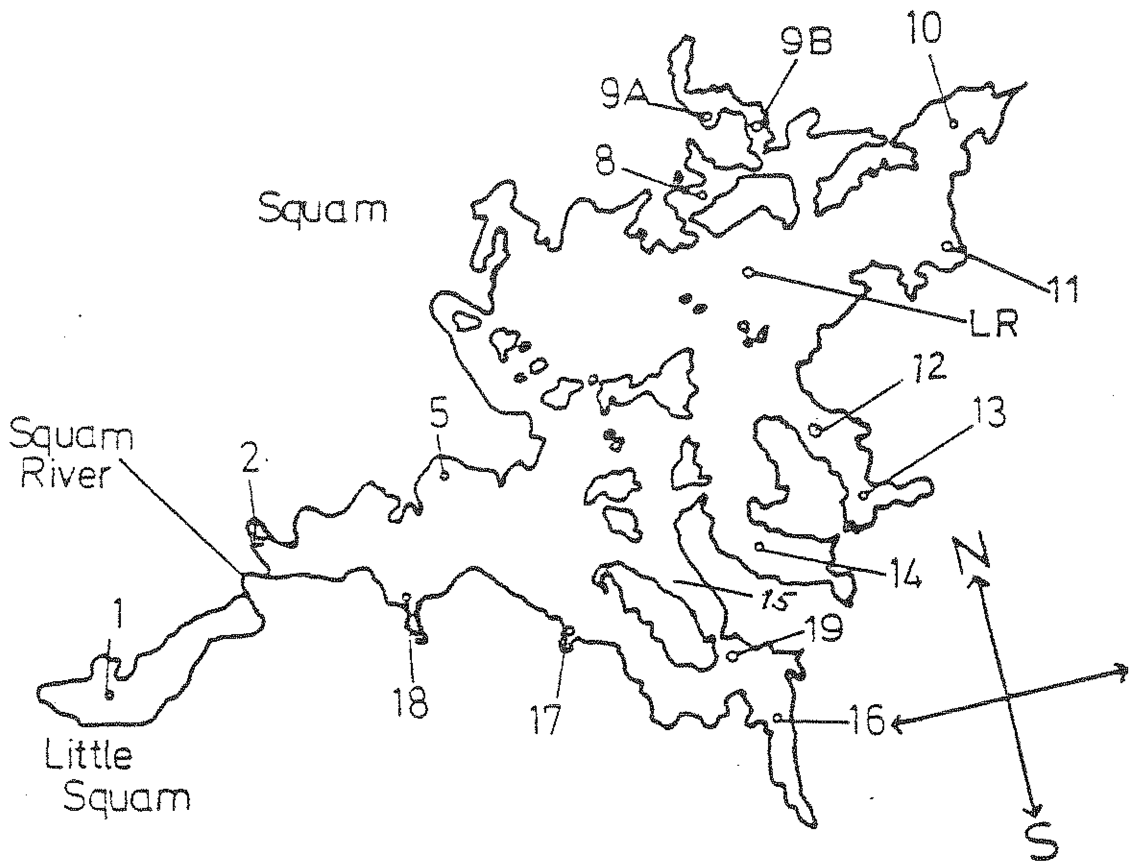

Figure 1. Squam Lake and Little Squam Lake, Town of Holderness, Grafton County, New Hampshire. Outline map and location of 1982 sampling sites.

Lay monitoring sites and maximum depth:

Little Squam	21.6 m	12. Moultonboro Bay	15 m.
2. Cotton Cove	8.7 m	13. Bean Cove	8.6 m
5. Livermore Cove	9.4 m	14. Sturtevant Bay	10.4 m
8. Rattlesnake Cove	7.9 m	15. Center Harbor	13.0 m
9A. Squam Cove (inner)	5.0 m	16. Dog Cove	7.9 m
9B. Squaw Cove (outer)	5.0 m	17. Hodges Cove	9.0 m
10. Sandwich Bay	18.4 m	18. Piper Cove	14.3 m
11. Kent Island	11.1 m	19. Mouse Island	8.9 m

Sites monitored by UNH FEG team:

Little Squam; Loon Reef (LR, 19.5 m), and Deephaven (D, 30 m)

The dissolved substances that give color to water are primarily <u>humic acids</u>, also called <u>yellow organic acids</u> or <u>gelbstoff</u> or <u>gilvin</u>. The color is similar to tea or weak coffee, and is caused by the large-scale decay of terrestrial or bog plants by fungi. The tea-colored substance cannot be broken down easily by the fungi, so it remains in solution and enters the lake either as surface run-off, or as bog discharge via streams. Also, deciduous leaves (especially hardwoods) may be abundant in small ponds, and be a direct source of humic substances as they decay within the pond.

The presence of a large amount of suspended particles, or tea-water, or both, can have a strong influence on <u>visibility</u> of large objects that are placed under the surface. For example, a well-known standard test for the degree of water transparency is the <u>visibility disc</u> or Secchi Disk. The depth at which the 8-inch (20 cm) diameter disk disappears as it is lowered downward is called the <u>Secchi Disk Depth</u>, or water transparency. The numerical value of water transparency may vary from a few inches (about 0.2 meters) to more than 40 feet (12 meters), depending upon the transparency of the lakewater.

Chlorophyll _a_ is a green pigment used in photosynthesis by plants, and present in all green plants -- including the microscopic algae suspended in the open waters of a lake (phytoplankton). The chlorophyll _a_ concentration of lakewater is a useful estimator of phytoplankton abundance, and thus is also an indicator of the primary productivity of the lake, and of the degree of _eutrophication_ in the lake. The range of variation of the pigment throughout the ice-free period, or at least the summer period, as well as its average value for the same time period, is a tool useful in comparing the relative _trophic state_ of lakes. A high maximum value of chlorophyll _a_, and a high variability of values, suggests that the lake is _eutrophic_. Low and relatively constant values indicate a low _trophic state_ -- oligotrophy.

1. Little Squam Lake

Secchi Disk Transparency and Chlorophyll _a_

Secchi Disk Depth (water transparency) averaged 6.2 meters during 1982 (Fig. 2). Maximum water transparency in Little Squam occurred on August 16 (7.5 meters) and minimum on July 6 (4.5 meters). Generally the greatest transparency occurred during August and September (Appendix A).

Chlorophyll a averaged 2.1 milligrams per cubic meter during 1982 in Little Squam Lake (Fig. 3). No seasonal trend was apparent. The average chlorophyll concentration was the highest -- and the water transparency was the lowest -- since the LLMP began in 1979 (Appendix A).

Average chlorophyll a concentration of the lay monitor data has increased each year since 1979. A corresponding trend of decreasing water transparency may be seen (Fig. 4). A possible trend toward eutrophication of Little Squam Lake is discussed in the Summary section.

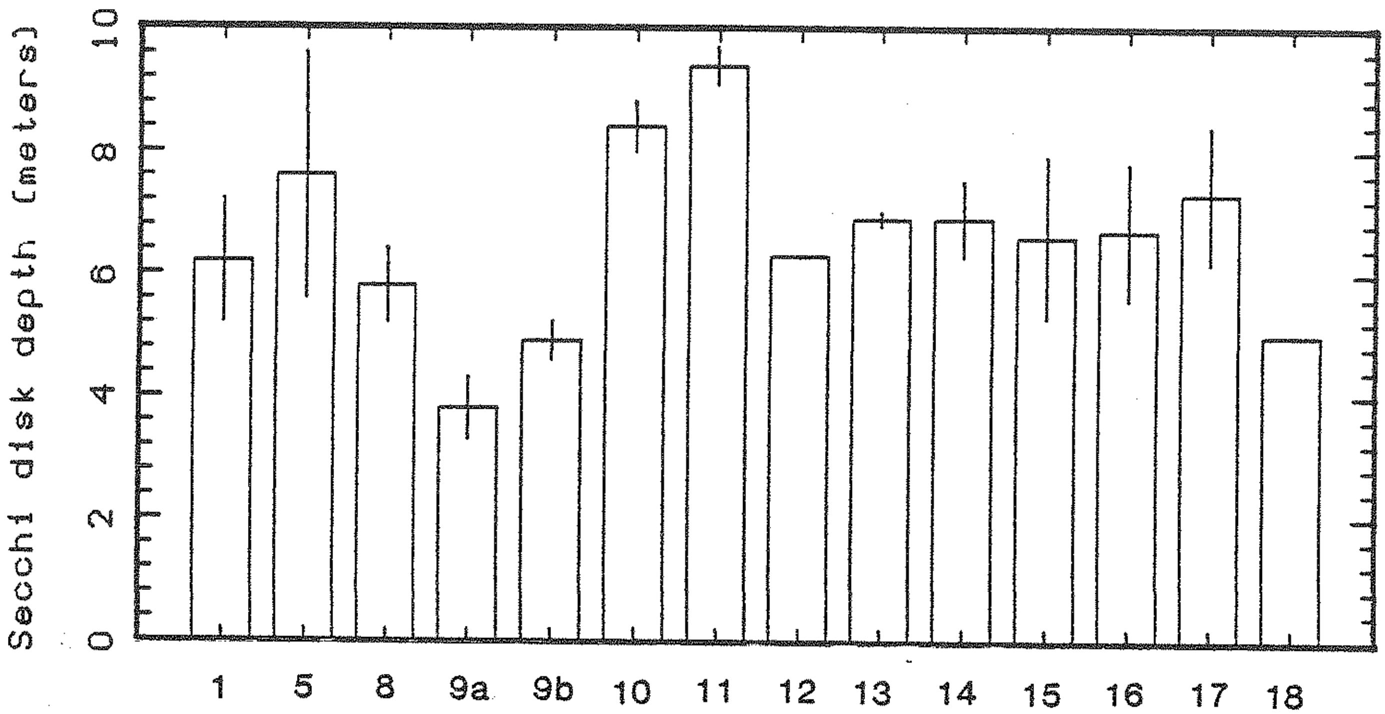

Figure 2. Water transparency (Secchi Disk Depths) through the summer of 1982 in the Squam Lakes at all stations.

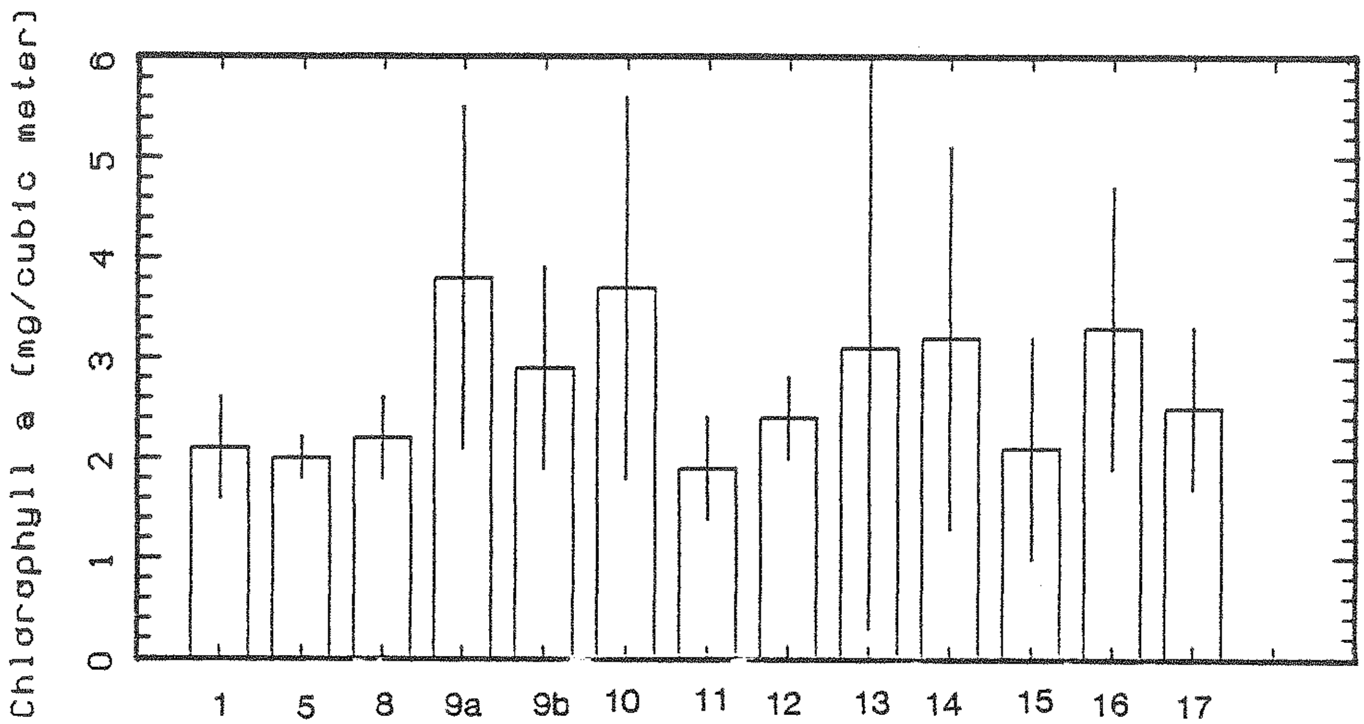

Figure 3. Chlorophyll *a* concentration through the summer of 1982 in the Squam Lakes.

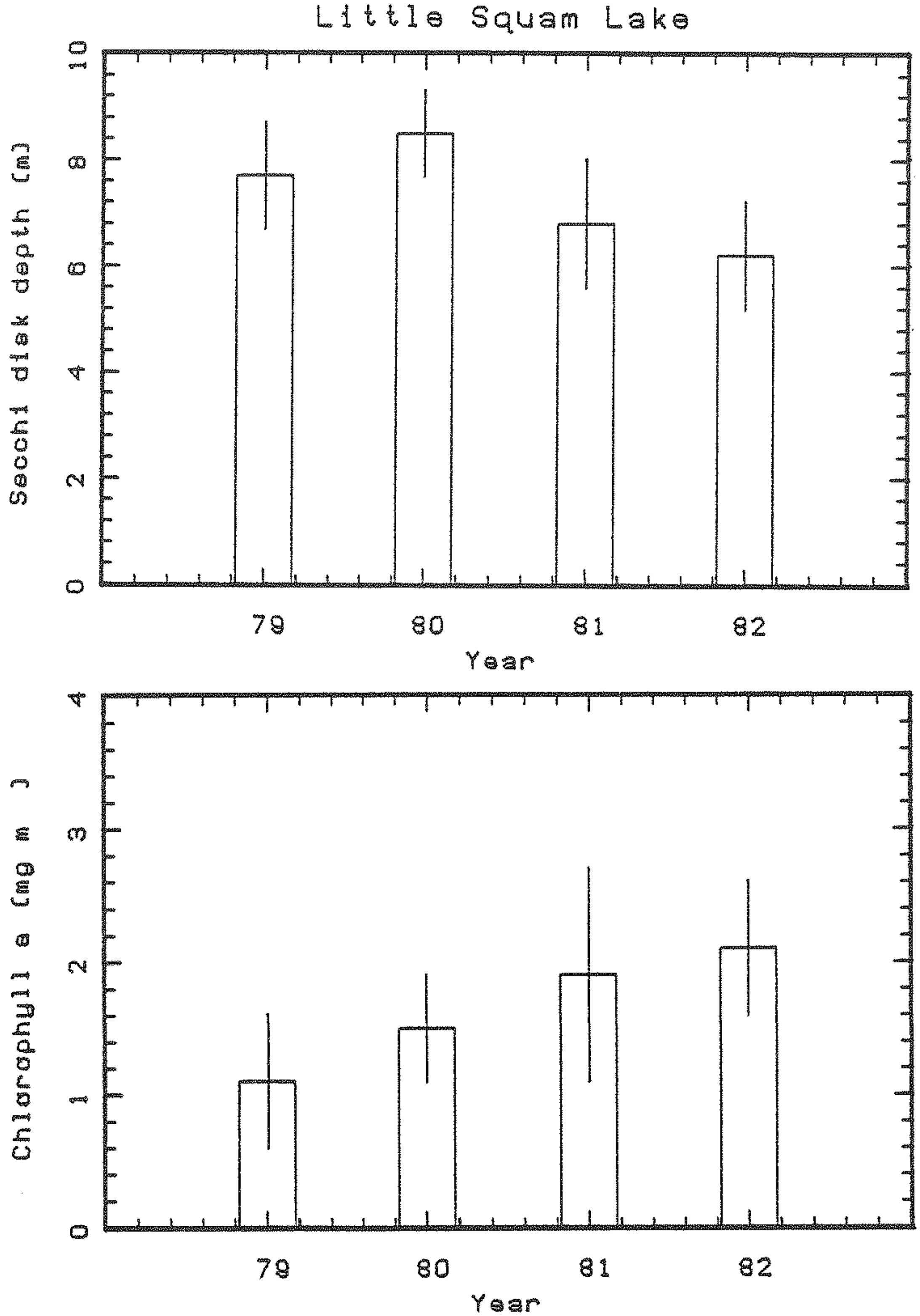

Figure 4. Summer averages of chlorophyll a and Secchi disk depth in Little Squam Lake, 1979 - 1982.

2. Squam Lake

Average Secchi Disk depth (water transparency readings) of all sites combined (excluding sites 9A and 9B) during 1982 was 7.2 meters. Of the deepwater stations the greatest depth was found at Kent Island (9.4 meters) and the shallowest at Rattlesnake Cove (5.8 meters). In the shallower Squaw Cove (sites 9A and 9B) water transparencies were 3.8 and 4.9 meters respectively (Fig. 2). Because these transparency depths represent nearly the entire water column they may not be indicative of the water transparency. The widest range of transparency values was at Center Harbor Neck (site 15) (5.3 to 9.5 meters).

Chlorophyll a concentrations have increased during the past four years (1979 - 1982) suggesting an increase in productivity in Squam Lake. No clear trend in water transparency can be seen (Fig. 5).

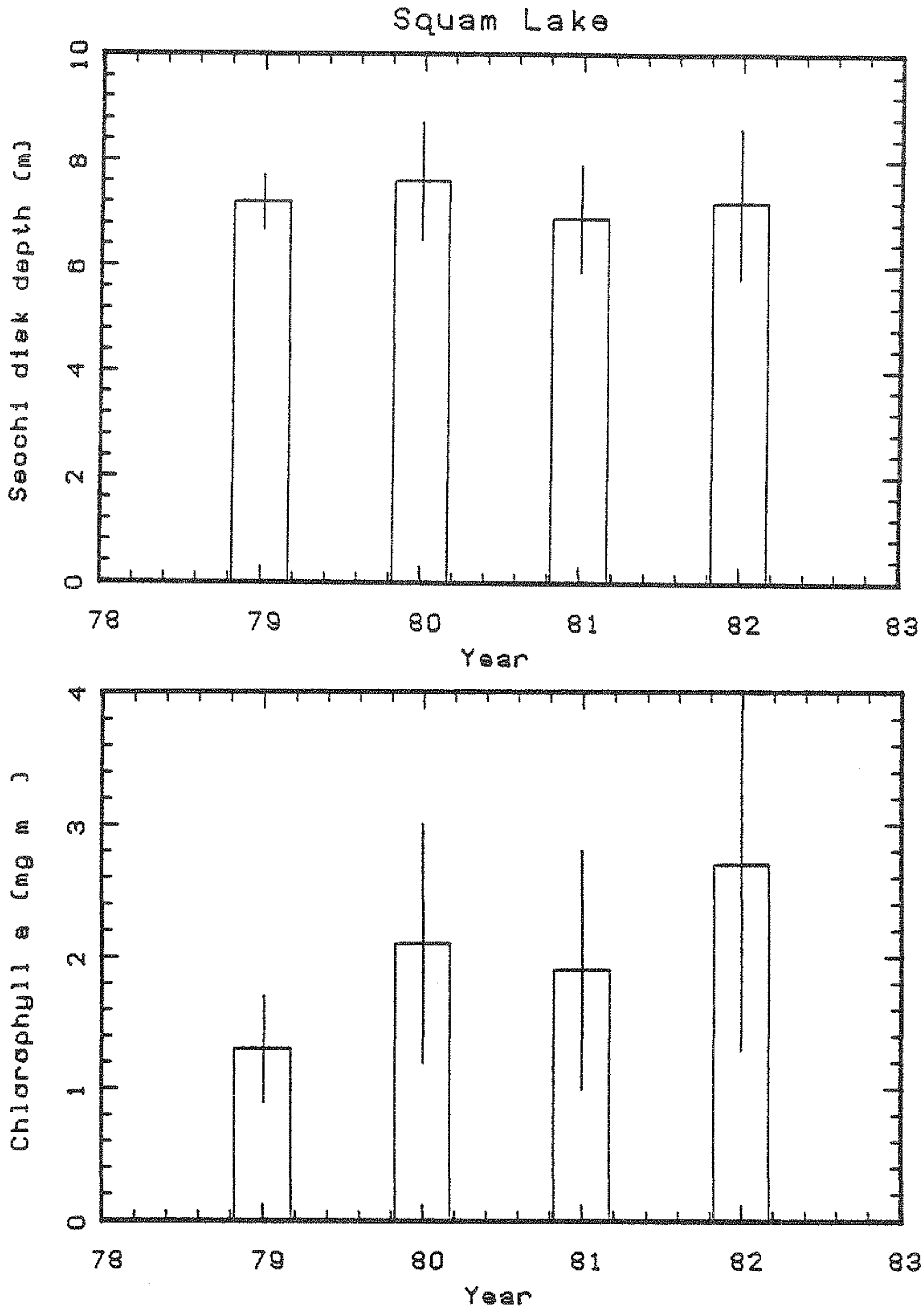

Figure 5. Summer averages of chlorophyll a and Secchi disk depth in Squam Lake, 1979 - 1982.

ph, Water Temperature and Dissolved Oxygen

The pH at the surface was measured with a portable pH meter, and profiles of temperature and dissolved oxygen were measured with an electronic probe and thermistor by Mr. Richardson Blair and Mr. B. Kim Ayers.

At the Deephaven site the pH was 6.9 on August 18 and 6.6 on September 10. Surface pH at Sandwich Bay varied from 6.2 (August 18) to 6.8 (September 10). At Loon Reef the surface pH was 6.9 on August 18.

Profiles of both temperature and dissolved oxygen presented in figures 6 and 7 indicate that deepwater sites were stratified prior to mid-August. The upper boundary of the thermocline was at 7 meters on August 18. By September 10 the upper boundary had moved down to 10 meters at all three sites.

A decrease in the concentration of dissolved oxygen was evident in the hypolimnion (below 15 meters at Loon Reef and Sandwich Bay, and below 20 meters at Deep Haven) on August 18. Somewhat lower oxygen concentration was found in Sandwich Bay, with less than 4 ppm -- approximately the minimal level for long-term survival of lake trout.

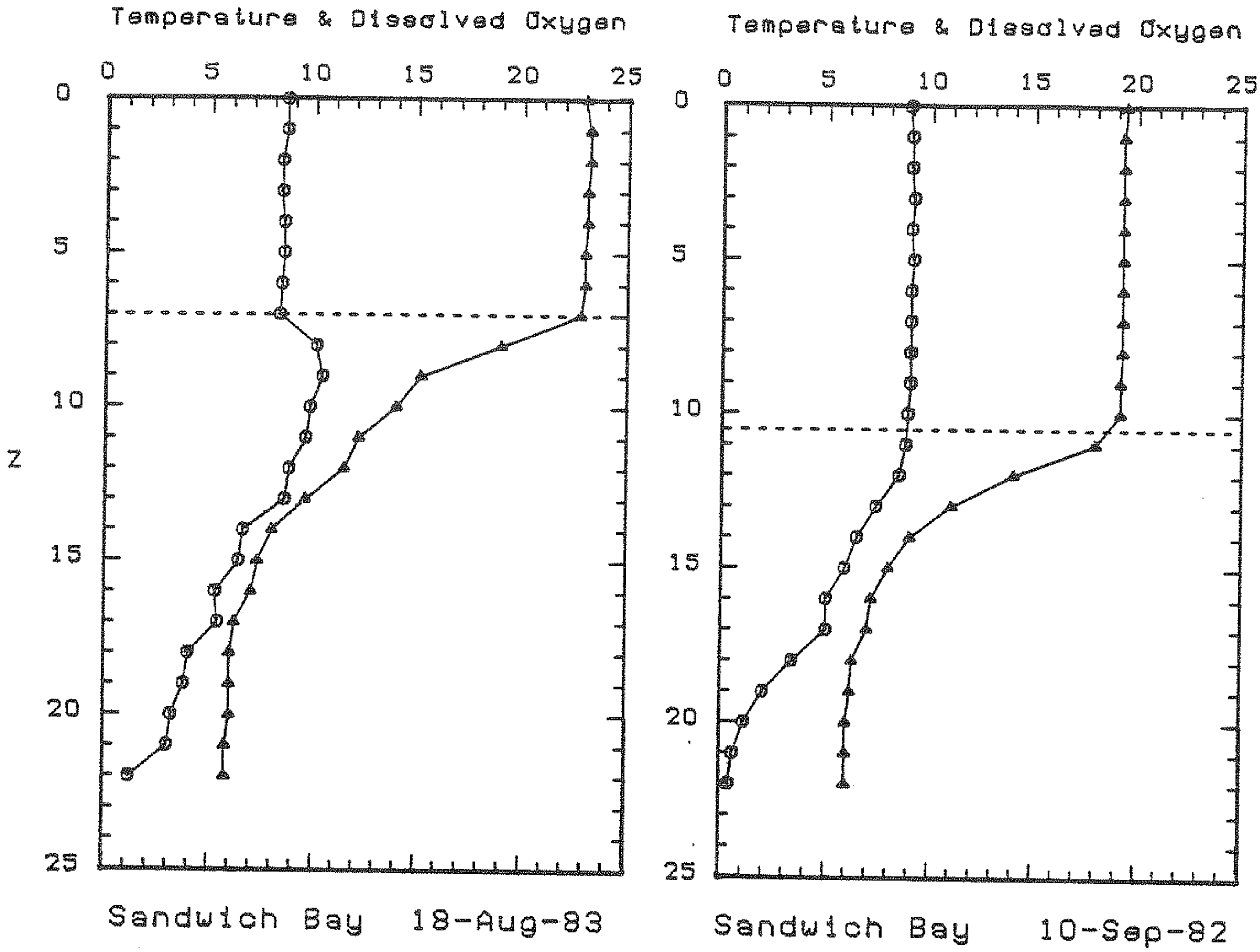

Figure 6. Profiles of temperature and dissolved oxygen at Sandwich Bay. [Richardson Blair and B. Kimball Ayers.]

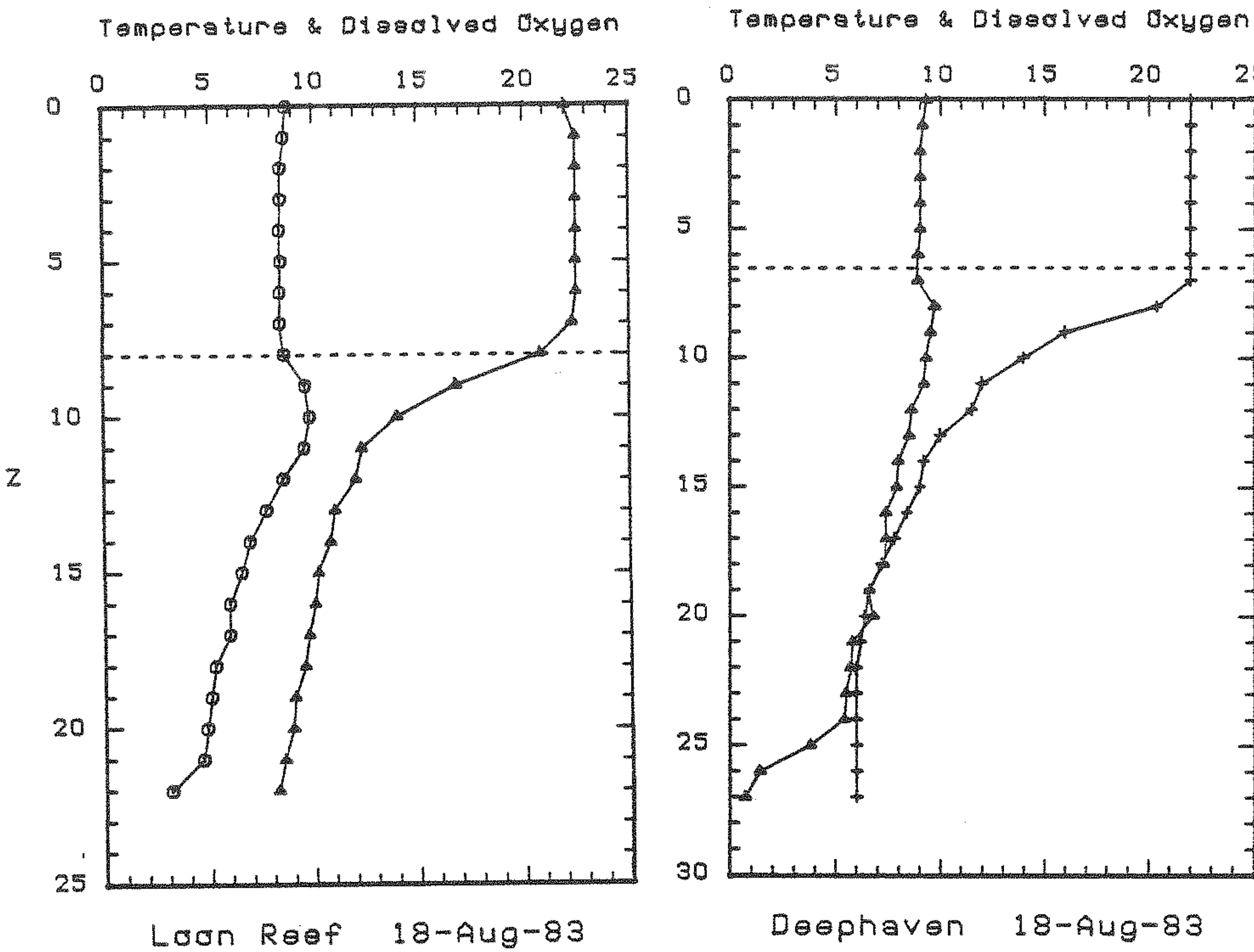

Figure 7. Profiles of temperature and dissolved oxygen at Loon Reef and Deephaven. [Richardson Blair and B. Kimball Ayers.]

RESULTS AND DISCUSSION OF FRESHWATER BIOLOGY GROUP DATA

Squam Lake and Little Squam Lake

Temperature and Dissolved Oxygen

Little Squam and Squam Lake developed a thermal stratification by the first week of June and remained stratified into October (figs. 8 - 10). The summer hypolimnetic water temperature remained below 5 C in Little Squam and approximately 6 C at Deephaven in Squam lake. At the Loon Reef site in Squam Lake the hypolimnetic water temperature was considerably warmer (ca. 10 C), indicating that the site was subjected to greater wind action and mixing during the spring, when thermal stratification was developing. The maximum surface temperature of 22.5 C was recorded on Little Squam on August 13. The highest temperature recorded on Squam Lake during the summer was 24.1 C on July 26.

Water Clarity or Transparency

Secchi Disk Depths (water transparencies) in Little Squam Lake (site 1) were minimal (5.3 meters) from June to early August, and increased in mid-August to 7.5 meters. These results support the lay monitor data.

Water transparencies measured in Squam Lake were somewhat greater (Table 1).

Chlorophyll *a*

The chlorophyll *a* concentrations in Little Squam and Squam Lakes collected by the FBI team compared favorably with data from the Lay Monitors (Table 1). The relatively high value of chlorophyll at Deephaven on June 9 may be an indication of large populations of phytoplankton during the spring, probably growing rapidly from the time of ice-melt, and suggests the need for early-season sampling.

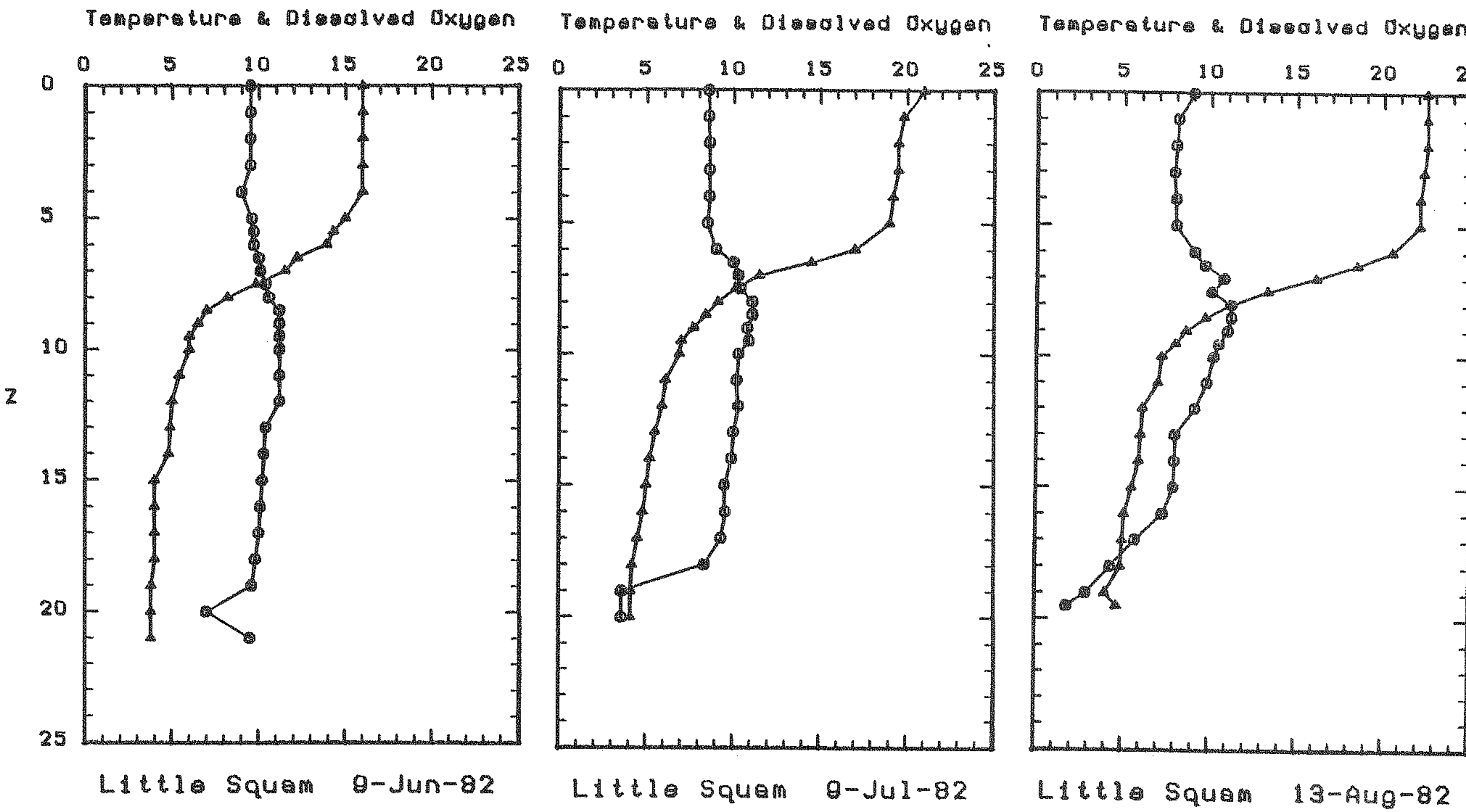

Figure 8. Profiles of temperature and dissolved oxygen in Little Squam Lake in June, July and August, 1982. (Triangles: temperature; circles: dissolved oxygen.)

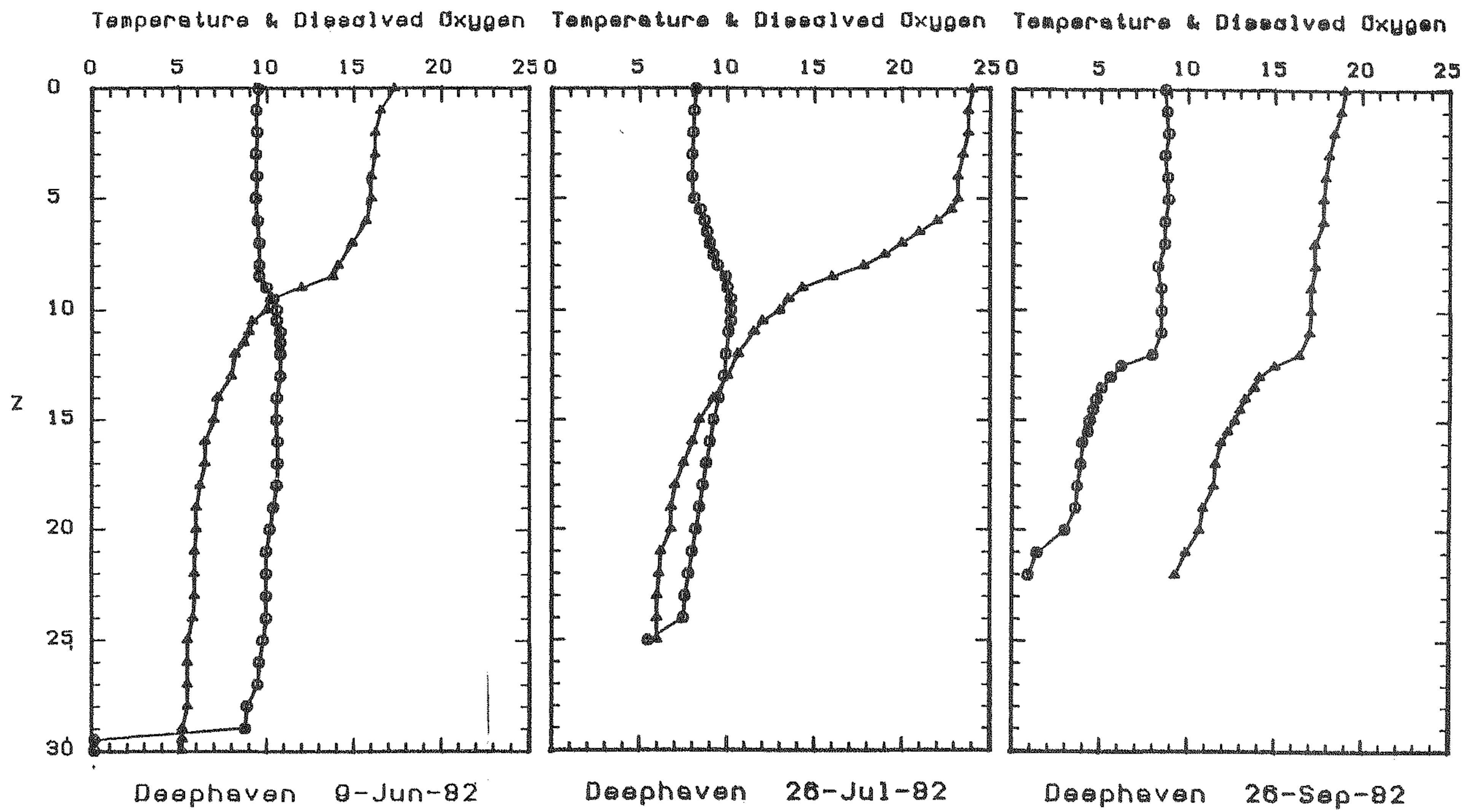

Figure 9. Profiles of temperature and dissolved oxygen at Deephaven, Squam Lake during summer 1982. (Triangles: temperature; circles: dissolved oxygen.)

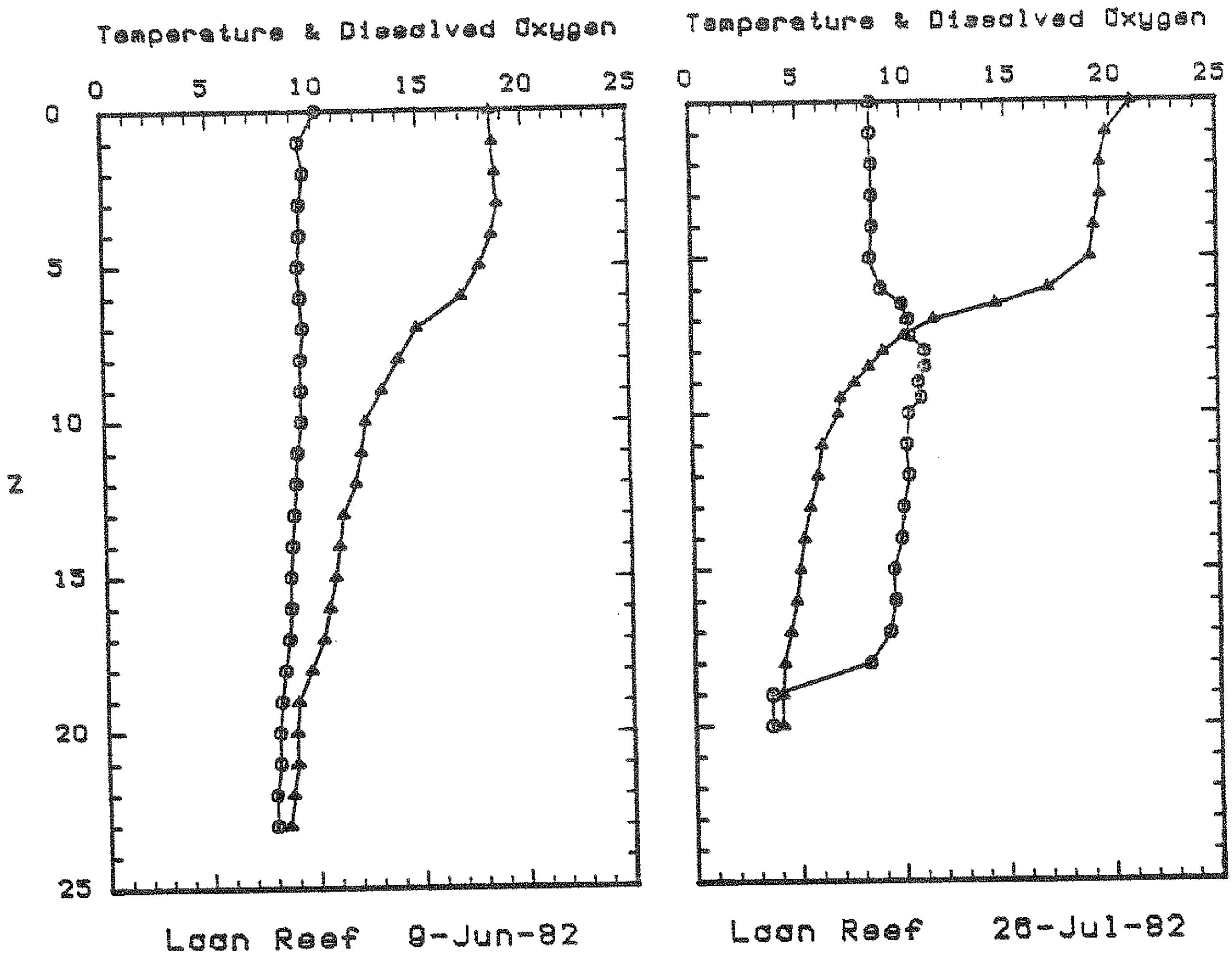

Figure 10. Temperature and dissolved oxygen profiles at Loon Reef on June 9 and July 26, 1982. Data from the FEG team, UNH.

Table 1. Secchi disk depths (meters) and chlorophyll (mg per cubic meter) data collected by the FBG team.

Site	DATE	SD	CHL. a
Little Squam	June 9	11.5	---
	July 6	5.3	---
	Aug. 13	7.5	1.4
Deephaven	June 9	8.3	5.4
	July 26	8.0	1.9
Loon Reef	July 26	8.9	2.0

Total Phosphorus

The total phosphorus concentrations in early June were approximately 10 micrograms per liter (10 ppb) in both Little Squam and Squam Lake. These values are comparable to the range of values measured in 1981 in Little Squam (7 to 15 micrograms per liter) and are somewhat higher than the range for Loon Reef in 1981 (5 - 7 micrograms per liter).

pH, Alkalinity and 'free' Carbon dioxide

The lakewater surface pH values in Little Squam Lake were 6.8 on three sampling dates (June - August). pH values at Deephaven in Squam Lake were in the range 6.3 - 7.0, with an average pH of 6.5. The range of pH values at Loon Reef was 5.6 - 7.1 with an average pH of 6.0. The average pH at each site was somewhat lower in 1982 than in 1981. However, the differences between two years cannot be taken as an indication of acidification in the lakes. Data from several years will verify or refute these short-term observations. Note: 'Average' pH is calculated from the hydrogen ion concentrations calculated from the pH measurements -- not from the pH readings themselves.

No change in alkalinity was observed in 1982 relative to previous years. The range of alkalinity values in the epilimnion of Little Squam was 5.1 to 12; in Deephaven (Squam Lake) 5.0 - 7.0, and at Loon Reef 3.5 - 7.1 mg CaCO per liter. The slightly higher values such as those in Little Squam are generally associated with higher rates of primary production and greater nutrient loading. The alkalinities agree with values obtained by the Water Supply and Pollution Control Commission (State of New Hampshire) in 1979 (6 milligrams per liter CaCO in Little Squam and 4 milligrams per liter at Deephaven in Squam Lake). It is interesting to note that such values are all much lower than the respective values obtained approximately 50 years ago by the NH Fish & Game Commission, of 16 milligrams per liter in Little Squam Lake and 20 milligrams per liter in Squam Lake. If these differences are real, and not subject to a change in methods, acidification' of the Squam lakes has occurred and the lakes now have a much lower buffering capacity than in the past -- probably a result of acid rain.

In addition to dissolved oxygen, the concentration of carbon dioxide in the hypolimnion provides an other useful indication of the amount of decomposition occurring there. In very oligotrophic lakes the CO levels would generally remain below 2 to 3 mg per liter, whereas in highly productive, polluted lakes one would expect to find high levels of CO in the deep water. Relatively high values of CO developed in the deepest waters near the sediments by September. For example at Deephaven at 18 meters, the concentration was 18 mg per liter. Similarly high values occurred in the lower hypolimnion of Little Squam lake. The concentration, as well as the <u>total</u> <u>accumulation</u> of CO in the hypolimnion should be monitored over long periods as a means of detecting changes in productivity of the lakes.

<u>Phytoplankton</u>

Phytoplankton -- microscopic algae -- samples were taken in Little Squam Lake on July 6 and in Squam Lake, at both Loon Reef and Deephaven sites, on July 26. As in previous years the dominant <u>classes</u> of algae were the diatoms (Bacillariophyceae), greens (Chlorophyceae), goldens (Chrysophyceae) and (at least in Little Squam Lake) cryptomonads (Cryptophyceae). The total concentration at all sites was in the range 500 - 900 individual organisms per milliliter.

The algal community in Little Squam Lake had a greater diversity of species and a relatively greater proportion of centric diatoms than Squam Lake. Both of these differences would suggest a higher level of productivity and/or eutrophication in Little Squam. However, the difference in sampling dates (approximately 3 weeks earlier in Little Squam) would also be a factor, so the algal data alone must be seen only as supporting other data, rather than confirming, that Little Squam is more eutrophic than Squam Lake (deep sites).

Of concern is the presence of blue-green bacteria in small numbers at both lakes. In previous years (see 1980 report, Table 3, for example) the blue-green bacteria (also called algae) were even more abundant. However the maximum abundance has never been more than 800 individuals per milliter, and day-to-day diffences can account for the lower numbers recorded in 1982. Part of the daily variability is due to weather, including changes in wind direction or velocity, and changes in the amount of flooding from rainstorms. The heavy rainfall during June 1982 may have influenced the phytoplankton community, strongly suggested by the large numbers of Cyclotella and Stephanodiscus (centric diatoms) during early July. In previous years these organisms were found in June in large numbers, but declined during early July. Thus the seasonal pulse appears to have been delayed by the prolonged stormy period in June.

Zooplankton in Squam Lakes

Zooplankton samples were taken from one site in Little Squam Lake (site 1) and two sites in Squam Lake (sites Deephaven and Loon Reef). Total crustacean zooplankton densities were 8 individuals per liter on June 9 and 6 individuals per liter on July 6 at Little Squam Lake site. On both occasions the dominants were calanoid copepods and in July Bosmina was also abundant. Densities of Daphnia, an important zooplankton grazer, were conspicuously low with less than 1 individual per liter at both times.

Highest densities of planktonic crustaceans were recorded at the Deephaven site on June 9 with 15 individuals per liter. At that time the dominant zooplankter was Daphnia with 11 individuals per liter. Also relatively abundant was the cladoceran Holopedium. The high numbers of Daphnia and corresponding high grazing potential at Deephaven are in contrast to the population in Little Squam Lake on the same date. Total herbivorous crustacean densities on July 26 were considerably lower at Deep Haven and Loon Reef sites, with 2 to 3 individuals per liter. At that time the dominant crustaceans were calanoid copepods, Bosmina and Holopedium. In lesser abundance were cyclopoid copepods, Daphnia and Polyphemus. In all cases the large crustacean zooplankton were rare by late July. This is probably related to higher predation pressure by fish at that time, especially by newly-hatched fry that appear in early to mid-summer.

Zooplankton populations in the Squam Lakes were comparable in size and composition to previous years' data from the LLMP. The dominance of the large herbivorous crustacean cladocerans, Daphnia and Holopedium, in Deephaven is of special interest since these organisms are efficient grazers and when present in sufficient abundance may suppress the density of small phytoplankton thereby contributing to greater water transparency.

SUMMARY

FUTURE OF THE SQUAM LAKES LLMP

1. pH and Buffering Capacity

Problems associated with 'acidification' of lakes by acid rain usually begin near pH values of approximately 5.0. The pH of the epilimnetic (upper) water in Squam Lakes is presently above 5.0, although the pH in the deeper water frequently approaches this 'danger' level. Based on the low alkalinity values in both Squam and Little Squam Lakes the lakewater has a very poor buffering capacity -- very little capacity to resist a change in pH (downward) when acid rain is added. The average epilimnetic (upper water) pH values in Little Squam Lake (6.8) and in Deephaven (6.5) do not indicate any significant change in acidity during the past eight years. However, the lower average pH recorded in 1982 at Loon Reef (6.0) suggests some influence of acid rain in this region.

An important aspect of the acidification process is that it is not constant with time, but rather follows a pattern of slow acidification during the early stages, and then rapidly accelerates as the buffering capacity of the lakewater is exhausted. This poses an interesting question: When will the buffering capacity (alkalinity) of the Squam Lakes disappear? A comparison with alkalinity measurements for the Squam Lakes made in the 1930's indicates alkalinities have decreased in that period. However, since the methods of analysis are now different it is difficult to make a quantitative comparison. It is apparent that a model capable of predicting the point in time when the 'buffering capacity' will be exhausted would be extremely valuable. We must rely on the LLMP to provide data for such a model.

The acidification process (decreasing alkalinity and pH) may occur slowly in some lakes such as Squam Lake because of the long residence time of the large volume of water contained in the basin, relative to the rate of supply in the inflow. For example, the residence time of Squam Lake is approximately 4.3 years, and of Little Squam is 5 months. For comparison, the residence time for Newfound Lake is 2.4 years, and Lake Winnipesaukee is 5.7 years (NHWSPCC 1981). The world's largest lakes, such as Lake Superior, have residence times in centuries. In contrast, the residence time in Lake Chocorua is only 2 months, and thus one might expect it to respond more rapidly to the effects of acid rain. Unfortunately, while the acidification process may be slow, the reversal of the process, bringing back the alkalinity, is equally slow. Therefore it is important to recognize even small changes in pH and alkalinity so that corrective measures can be taken during the early stages of acidification. It is important that an adequate data base for pH and alkalinity be established for the Squam Lakes. We suggest that an expanded program of pH and alkalinity monitoring be developed for the Squam Lakes, i.e. one that includes the early Spring period when pH 'depression' (lower pH due to melting of snow-pack and seasonal rainfall) of lakes and streams is commonly observed.

2. Trophic Status of Little Squam and Squam Lakes

One means of assessing the present status of Little Squam and Squam lakes is to compare the average Secchi Disk Depth (water transparency), chlorophyll *a* and phosphorus values with other New Hampshire lakes in the LLMP. It is also useful to see where these values lie in relation to established ranges for the trophic levels; oligotrophic (nutrient-poor, unproductive, 'clean' water), eutrophic (nutrient-rich, productive, 'green' water), and mesotrophic (waters with intermediate levels of nutrients and productivity). Recently the standards for the various trophic levels in lakes have been reviewed and reestablished by Forsberg and Ryding (1980). These provide a convenient scale by which to gauge the trophic status of the Squam Lakes (Figs. 11 - 13). By all three standards (Secchi disk transparency, chlorophyll *a* and total phosphorus) the Squam Lakes would be classified as oligotrophic. However, within the range of oligotrophy there is a range of values of each of the three parameters. Based on secchi disk depth and total phosphorus Squam Lake is more oligotrophic (i.e.

cleaner and less productive) than Little Squam Lake. However, there is a slightly higher chlorophyll concentration in Squam Lake, and thus Little Squam wculd be classified as somewhat more oligotrophic.

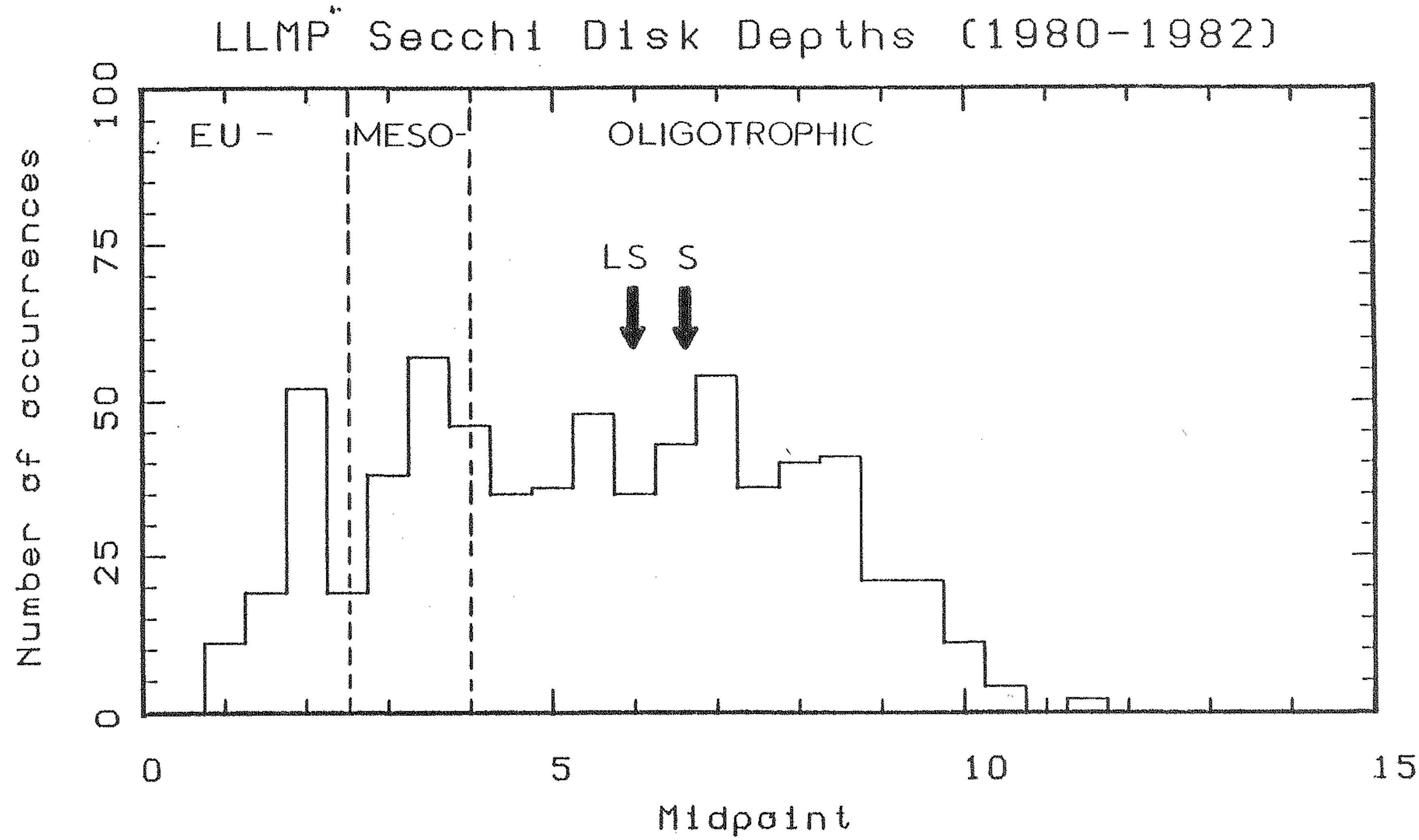

Figure 11. Position of the average Secchi Disk Depths (water transparency) during 1982 in Little Squam (LS) and Squam Lake (S) relative to all readings in all lakes in the LLMP.

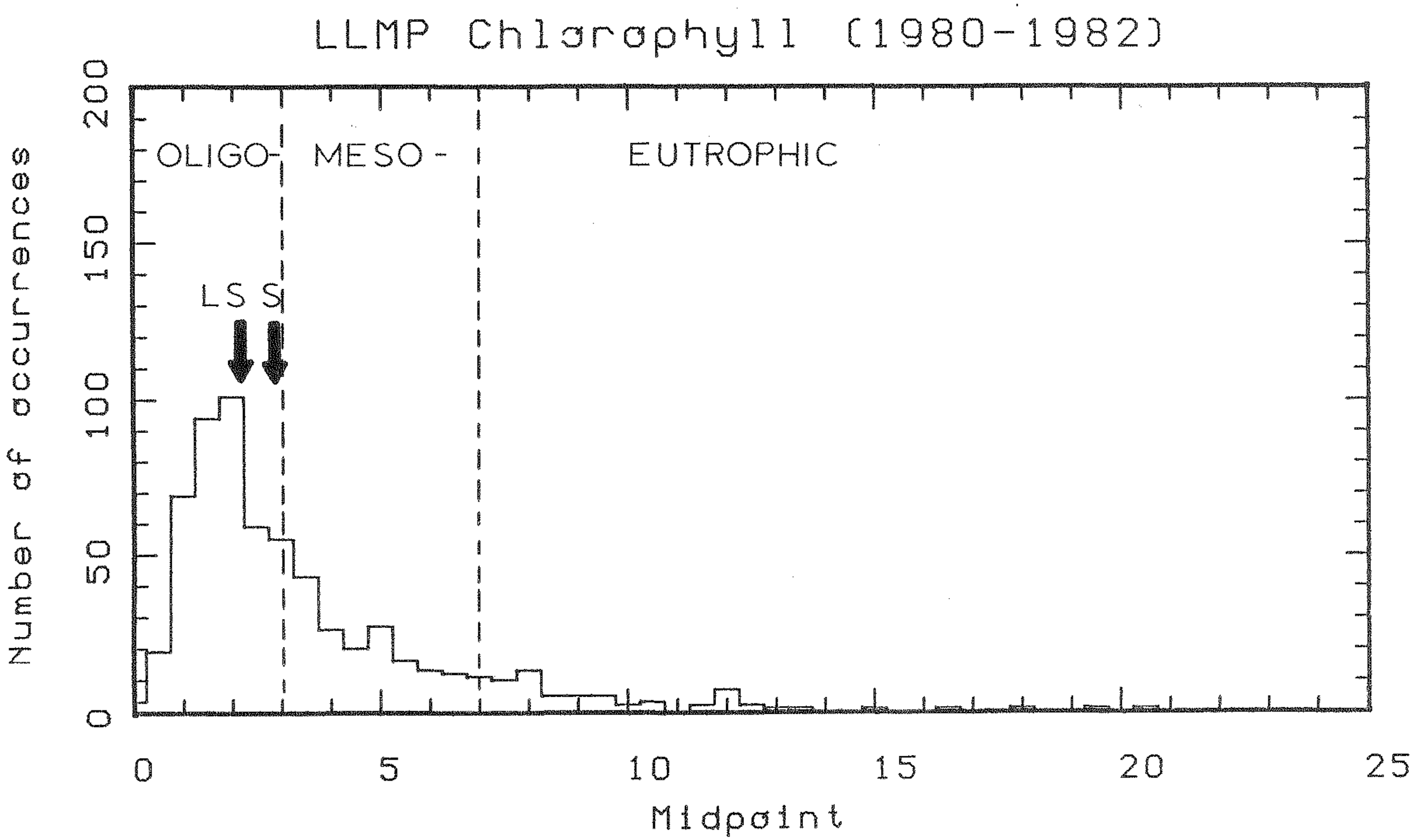

Figure 12. Position of the average Chlorophyll a values (mg per cubic meter) in Little Squam (LS) and Squam Lake (S) relative to all data from all lakes in the LLMP.

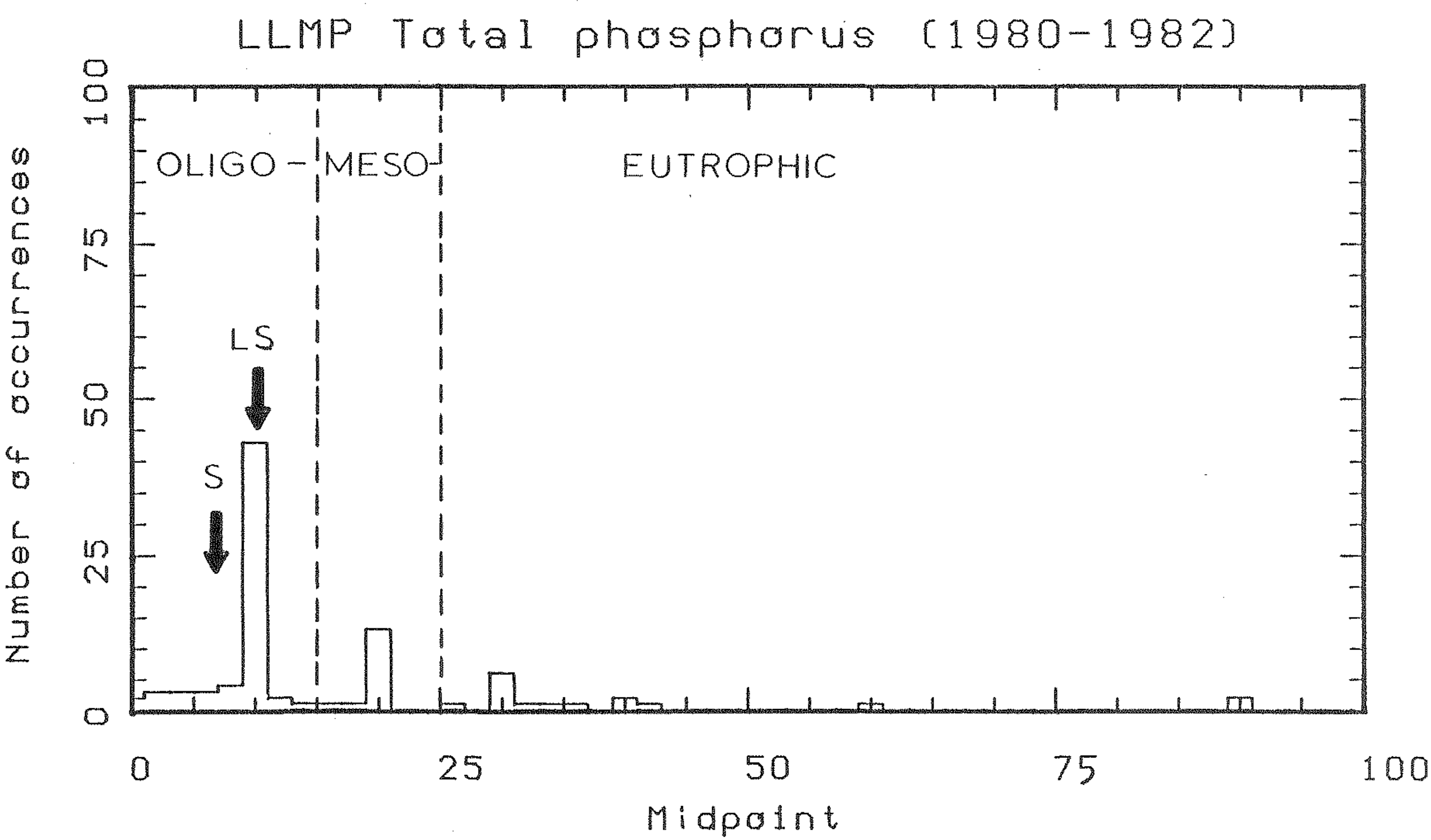

Figure 13. Position of the average phosphorus concentration (micrograms per liter) during 1982 in Little Squam (LS) and Squam Lake (S) relative to all data from all lakes in the LLMP.

3. Changes in trophic condition

An important feature of the LIMP is the development of a predictive model based on the data collected by the lay monitors. The accuracy of the predictions is dependent on the size and quality of the data base. To illustrate such a model we have taken the data from 1979 through 1982 for the secchi disk depths for Little Squam Lake (Fig. 14). Although four years of data limit the accuracy of long-range forecasting an impression of the usefulness of such models can be gained by this illustration.

For example, if one assumes the current trend of decreasing transparency will continue, by 1985 to 1986 the water transparency will have decreased to 4 meters, the boundary for mesotrophic lakes, and by 1990 Little Squam Lake should have reached a SDD of 2.5 meters -- which would classify it as eutrophic!

If a similar model is constructed for chlorophyll concentrations mesotrophic status will have been reached by 1986 to 1987, and the eutrophic level by the year 2000.

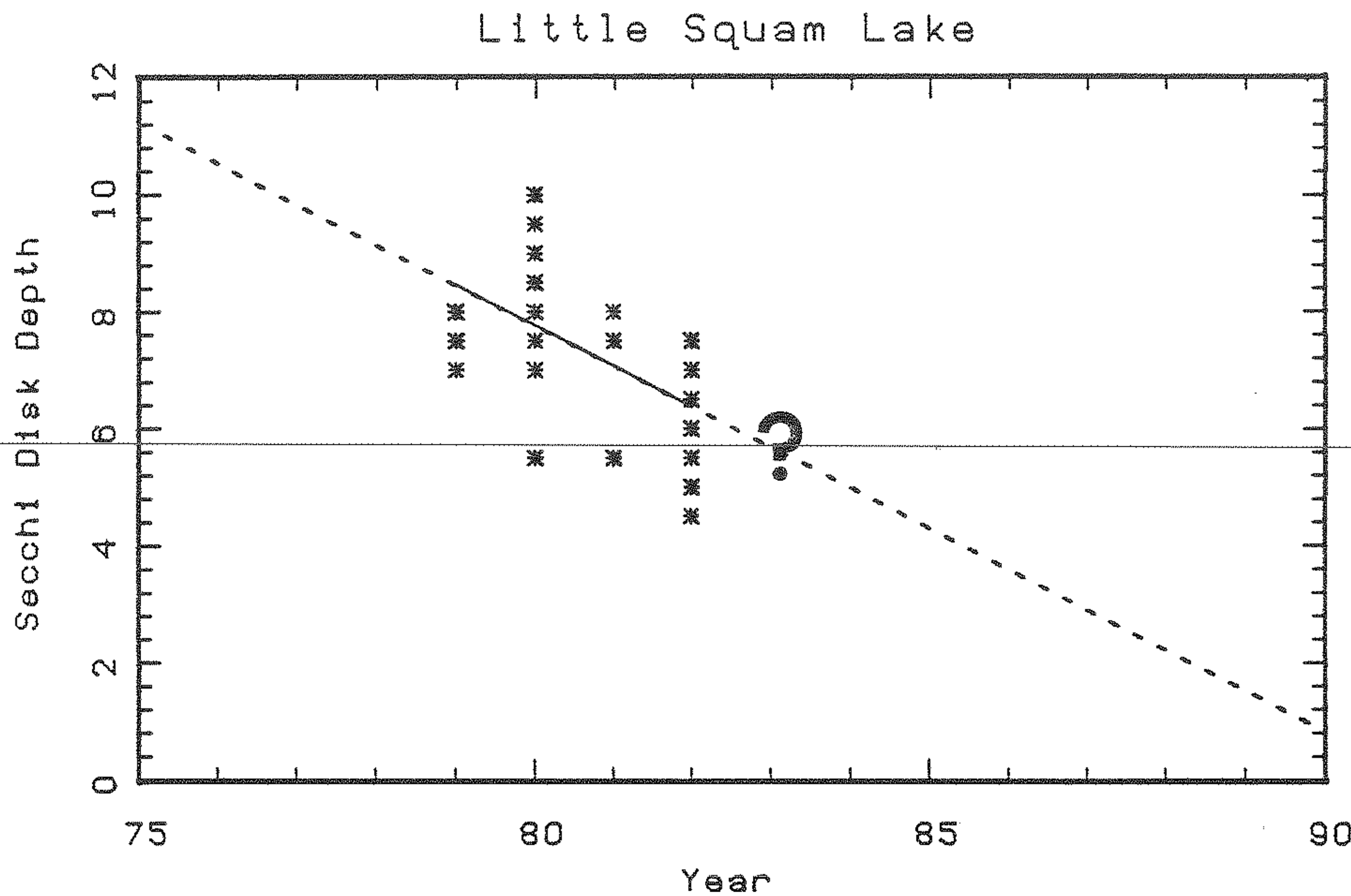

Figure 14. Linear regression model of changes in the secchi disk depth in Little Squam Lake. The model is based on data from 1979 to 1982. The solid line is a least-squares fit to the observations. The dashed line is a projection into the past and future. The '?' represents the predicted water transparency for 1983.

RECOMMENDATIONS

The accuracy of models DESCRIBING LONG-TERM CHANGES IN WATER QUALITY increases with each additional year of monitoring, and the predictions can be updated annually. Thus it is imperative that the Squam Lake Association continue to collect complete and accurate data.

A continuation of the Lake Lay Monitoring Program (LLMP) is recommended. The results from the fourth year of monitoring demonstrate conclusively that both lakes have relatively low productivity, a result of a limited nutrient loading and low annual recycling of nutrients from the bottom sediments. However, the gradual increase in chlorophyll a and total phosphorus, as well as decreasing water transparency, suggest that a general degradation by eutrophication is occurring. Continued monitoring is required to confirm and better define such trends. If 'eutrophication' continues, the next logical step is to determine the sources of nutrients for the lake.

The lay monitors on SQWUAM lakes have completed the fourth successful year of sampling, having provided a set of results that agree closely with those of the Freshwater Biology Group. This provides a solid foundation for the future monitoring of these lakes. In addition, the LIMP as conducted by members of the SLA is now a model program or standard by which others will be judged.

SPECIAL OBSERVATIONS

It IS always be important for monitors to report and even collect any observations of floating 'green scum' on the water surface, or of green 'flakes' (looking somewhat like grass clippings), or pale-gray 'spheres' (about 1/16th inch diameter) that may be seen occasionally below the surface when watching the descending secchi disk. Any of these may be evidence of blue-green bacteria pulses, possibly absent when the FBG team visits the lakes. The 'green scum' is generally a concentration of the bluegreens *Microcystis aeruginosa*, *Anabaena spiroides*, or even *Oscillatoria agardhii v. isothrix* and *Aphanizomenon flos-aquae*, along with other species. The 'grass clippings' are unusually large colonies of *Aphanizomenon flos-aquae*, and the 'spheres' are large colonies of *Gloeotrichia echinulata*. (The only commonly-found greenish-yellow scum not an alga is pine or spruce pollen that floats for several weeks after dispersal in June, and may be concentrated downwind.)

If you should collect any of these, please place not more than a teaspoon full of the lakewater in a small bottle (or zip-lock bag), add an equal volume of rubbing alcohol (or vodka, gin, whiskey, etc.) to preserve, and tape on a label that includes your name and the date and place of collection. We will identify the culprits, and include the observations in these reports.

REFERENCES

Brooks, J. L. and E. S. Deevey, Jr. 1963. New England. In: D. G. Frey (ed.), Limnology in North America. University of Wisconsin Press, Madison.

Carlson, R. E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-379.

Davis, R. B., J. H. Bailey, M. Scott, G. Hunt and S. A. Norton. 1978. Descriptive and comparative studies of Maine lakes. Life Sciences and Agr. Exp. Station, University of Maine. Technical Bulletin 88.

Environmental Protection Agency. 1979. A manual of methods for chemical analysis of water and wastes. Office of Technology Transfer, Cincinnati. PA-600/4-79-020.

Gallup, D. N. 1969. Zooplankton distributions and zooplankton-phytoplankton relationships in a mesotrophic lake. Ph.D. Thesis, University of New Hampshire.

Forsberg, C. and S.-O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-receiving lakes. Arch. Hydrobiol. 89:189-207.

Haney, J. F. and D. J. Hall. 1973. Sugar-coated Daphnia: a preservation technique for Cladocera. Limnol. Oceanogr. 18:331-333.

Hutchinson, G. E. 1967. A treatise on limnology, vol. 2. John Wiley and Sons, New York.

_____ 1973. Eutrophication. American Scientist 61:269-279.

Likens, G. E. 1975. Primary productivity of inland aquatic ecosystems. In: H. Lieth and R. H. Whittaker (eds.), Primary productivity of the biosphere. Springer-Verlag, New York.

Lind, O. T. 1979. Handbook of common methods in limnology. C. V. Mosby, St. Louis.

Lorenzen, M. W. 1980. Use of chlorophyll-Secchi disk relationships. Limnol. Oceanogr. 25:371-372.

NHWSPCC (New Hampshire Water Supply and Pollution Control Commission) 1981. Classification and priority listing of New Hampshire Lakes. Staff report no. 121. t.b1.i-5;Utermohl, H. 1958. Improvements in the quantitative methods of phytoplankton study. Mitt. int. Ver. Limnol. 9:1-25.

APPENDIX A

LLMP 1982 -- Lay Monitor Data   Jan-02-83   15:30.28

Date	Lake	Site	SDD	Chl
Jun-14-82	Little Squam	1 L.Squam	6.00	---
Jun-24-82	Little Squam	1 L.Squam	5.50	---
Jun-30-82	Little Squam	1 L.Squam	5.00	2.43
Jul-06-82	Little Squam	1 L.Squam	4.50	2.07
Jul-12-82	Little Squam	1 L.Squam	5.00	2.28
Jul-20-82	Little Squam	1 L.Squam	7.00	---
Aug-02-82	Little Squam	1 L.Squam	7.00	2.21
Aug-09-82	Little Squam	1 L.Squam	6.50	2.21
Aug-16-82	Little Squam	1 L.Squam	7.50	2.14
Aug-30-82	Little Squam	1 L.Squam	7.50	2.07
Aug-17-82	Squam	2 Cotton	8.00	1.80
Jul-17-82	Squam	5 Livermo	7.80	1.86
Jul-26-82	Squam	5 Livermo	4.80	---
Aug-03-82	Squam	5 Livermo	9.50	---

Aug-16-82	Squam	5 Livermo	8.20	2.17
Jul-16-82	Squam	8 Rattles	5.00	---
Aug-19-82	Squam	8 Rattles	6.50	2.07
Sep-05-82	Squam	8 Rattles	5.50	2.59
Jul-16-82	Squam	9A SquawI	3.50	7.28
Aug-01-82	Squam	9A SquawI	3.00	---
Aug-10-82	Squam	9A SquawI	3.80	3.26
Aug-16-82	Squam	9A SquawI	4.00	3.39
Aug-22-82	Squam	9A SquawI	3.80	2.93
Sep-05-82	Squam	9A SquawI	4.50	2.86
Jul-16-82	Squam	9B SquawO	5.00	3.57
Aug-01-82	Squam	9B SquawO	4.50	1.63
Aug-10-82	Squam	9B SquawC	5.00	---
Aug-16-82	Squam	9B SquawC	5.00	4.28
Aug-22-82	Squam	9B SquawO	---	3.12
Sep-05-82	Squam	9B SquawO	---	2.21
Aug-11-82	Squam	10 Sandwic	8.80	2.43
Aug-16-82	Squam	10 Sandwic	8.50	5.89
Jul-21-82	Squam	11 Kent Is	9.30	2.23
Jul-27-82	Squam	11 Kent Is	9.30	2.28

Aug-03-82	Squam	11 Kent Is	9.50	2.05
Aug-11-82	Squam	11 Kent Is	4.80	2.14
Aug-17-82	Squam	11 Kent Is	9.30	2.17
Aug-23-82	Squam	11 Kent Is	9.00	1.36
Sep-06-82	Squam	11 Kent Is	9.75	1.07
Aug-31-82	Squam	12	6.25	2.14
Sep-08-82	Squam	12	6.25	2.68
Jun-22-82	Squam	13 Bean Is	6.80	5.09
Jul-05-82	Squam	13 Bean Is	7.00	1.10
Jun-27-82	Squam	14 Bean Co	6.00	---
Jul-08-82	Squam	14 Bean Co	6.50	3.40
Jul-19-82	Squam	14 Bean Co	6.50	4.17
Jul-27-82	Squam	14 Bean Co	7.00	1.96
Aug-04-82	Squam	14 Bean Co	7.50	5.81
Aug-12-82	Squam	14 Bean Co	7.00	6.88
Sep-04-82	Squam	14 Bean Co	---	---
Sep-10-82	Squam	14 Bean Co	7.00	2.37
Jul-19-82	Squam	15	6.00	3.21
Jul-26-82	Squam	15	5.30	2.01
Aug-02-82	Squam	15	7.00	4.46
Aug-10-82	Squam	15	7.50	2.27

Jun-30-82	Squam	16 Dog Cov	4.50	4.00
Jul-13-82	Squam	16 Dog Cov	5.50	3.14
Jul-20-82	Squam	16 Dog Cov	7.00	2.72
Jul-26-82	Squam	16 Dog Cov	7.00	---
Aug-02-82	Squam	16 Dog Cov	7.50	---
Aug-10-82	Squam	16 Dog Cov	7.30	2.43
Aug-16-82	Squam	16 Dog Cov	8.00	2.86
Jun-25-82	Squam	17 Hodges	5.30	3.07
Jul-06-82	Squam	17 Hodges	10.00	---
Jul-21-82	Squam	17 Hodges	8.30	---
Jul-30-82	Squam	17 Hodges	7.50	---
Aug-04-82	Squam	17 Hodges	7.50	---
Aug-10-82	Squam	17 Hodges	8.30	---
Aug-16-82	Squam	17 Hodges	8.50	---
Aug-30-82	Squam	17 Hodges	6.50	2.00
Jun-27-82	Squam	18 Piper C	5.00	---

>>> END OF LIST <<<

APPENDIX E

CLARIFICATION OF SOME TERMS AND CONCEPTS

Thermal Stratification

Thermal stratification as a seasonal phenomenon is of prime importance in the lives of aquatic organisms. The formation of thermal layers affects many of the chemical and physical factors of their environment.

New Hampshire lakes are generally dimictic, with mixing of the water column occurring in the spring and fall. During periods of mixing, sometimes called overturn, the entire water column tends to circulate (holomixis). That is, the bottom-most waters are refreshed with water recently in contact with the atmosphere. The surface waters are enriched with water recently in contact with the bottom sediments. Some lakes, especially those with a high salt content toward the bottom of the basin, may be meromictic and fail to mix (overturn) to the bottom.

During the spring, the entire water column circulates freely, resuspending and redissolving material from the bottom sediments. As the sun's intensity increases, the surface waters are heated so that they become buoyant and tend to float, creating a mixing-barrier with cooler water beneath. Eventually three layers are formed, called the upper-lake (*epilimnion*), middle-lake (*metalimnion*), and lower-lake (*hypolimnion*) (Fig. B-1). Characteristically, the *epilimnion* and *hypolimnion* are uniform in temperature, even though the upper lake is warm and the lower lake is usually very cold. In contrast, the temperature gradually or suddenly becomes cooler in the *metalimnion* (sometimes called the *thermocline*, or temperature gradient). The gradation in temperature corresponds to a gradient in other important characteristics of water, such as viscosity and specific gravity, that explain the presence of a mixing barrier between the *epilimnion* and the *hypolimnion*.

Depth of the *metalimnion* through the summer is variable, and is regulated to a large extent by the length of the *wind-fetch* on the lake (the length of lake aligned with the predominant axis of wind-storms). In the autumn, the sun's intensity decreases, the water in the *epilimnion* cools, and the mixing barrier weakens. Eventually the *metalimnion* disintegrates and the fall *overturn* occurs.

Ice and snow insulate the lakewater during winter, and the liquid lakewater cools to nearly freezing just under the ice layer, while it remains relatively warm further down in the water column (about 10 degrees Fahrenheit, or 4 degrees Celsius). Sometimes the overburden of snow after a heavy snowstorm in January or February may cause melt-holes to form in the ice, and the snow may turn to slush even while the air temperature is at its seasonal coldest (as low as 25 or 30 degrees below zero Fahrenheit)! This has caused some hysteria about 'radioactive things dropping from outer space' or 'radioactive substances dropping from jet planes' -- even though it is only the weight of snow! Some reverse stratification may occur, with a layer of colder water overlying the relatively warmer water below.

Two aspects of the seasonal thermal stratification cycle about which we are most concerned are vertical mixing (overturn) and the formation of stratified temperature layers during the summer.

Periods of overturn are very important because of their effect of enriching the lakewater with material from the sediments. In eutrophic lakes, blooms of algae generally follow these periods in response to high concentrations of chemicals such as phosphorus, nitrogen, silica, and other essential nutrients -- those required for the growth of microscopic algae.

Effects of stratification will vary depending upon the depth of the lake or cove. In shallow areas, the epilimnion may extend to the bottom. If this is the case, the lakewater will constantly pick up material from the bottom usually resulting in a decrease in water transparency and an increase in algal growth.

One of the major consequences of a stratified lake system is reduced transportation of material between the bottom and surface. The effects of having a "barrier" within the water column are many but the most important include transport of nutrients from the epilimnion to the hypolimnion by sedimentation (enriching the hypolimnion at the expense of the epilimnion), and oxygen depletion in the hypolimnion.

Loss of nutrients from the epilimnion is due primarily to the sedimentation of plankton organisms such as algae and bacteria. The depletion of nutrients from the epilimnion is important for restricting the growth of algae during the summer, because the primary productivity of most lakes occurs only in the epilimnion. As a result of fall overturn the surface waters may become mixed with nutrient-rich bottom waters, and fall pulses of phytoplankton (freely-drifting microscopic algae) may develop.

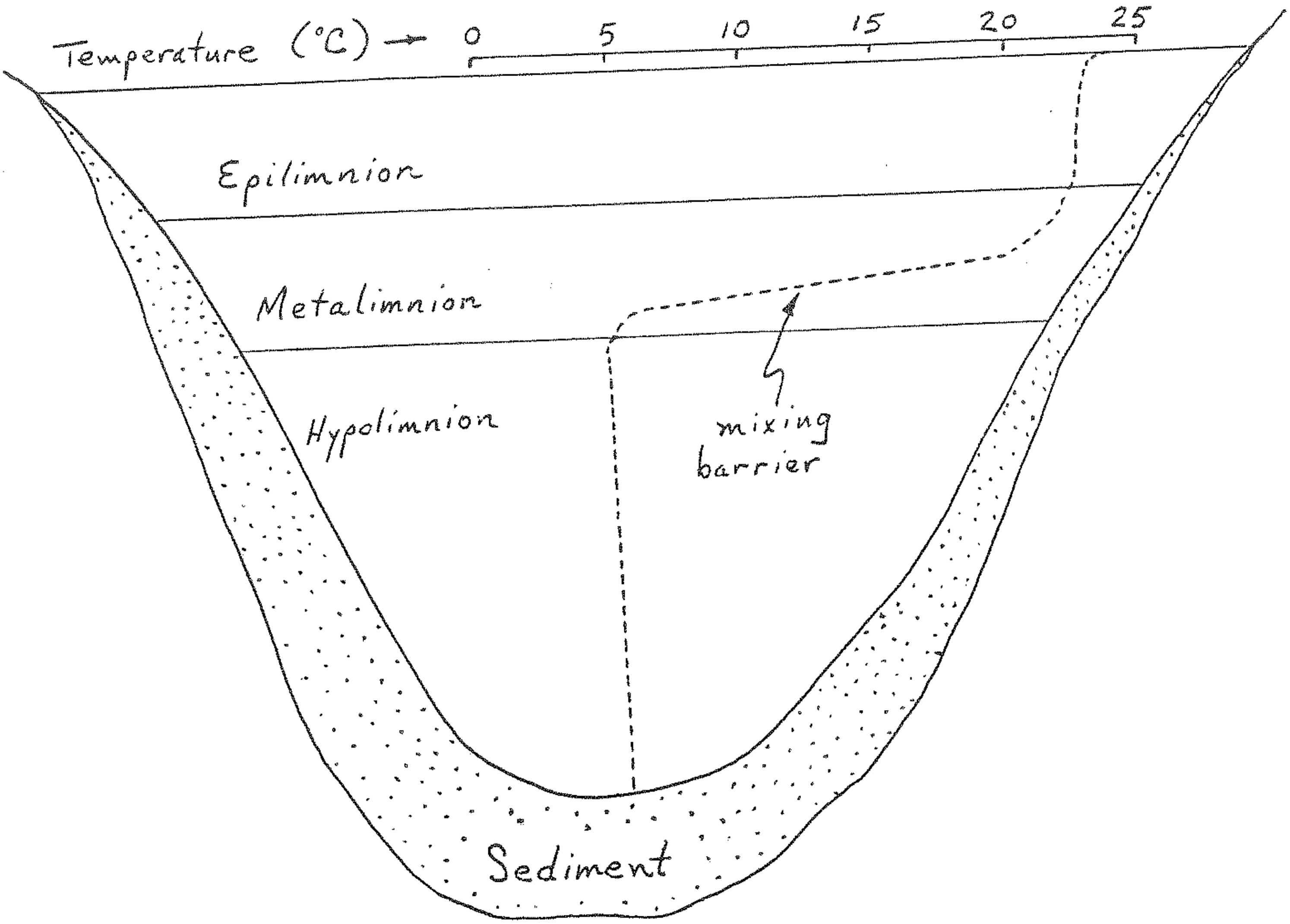

Figure B-1. Typical summer thermal stratification of a temperate lake. The 'metalimnion' provides a mixing barrier between the 'epilimnion' and the 'hypolimnion'. The dashed line represents the thermal profile, with cold water in the hypolimnion.

Oxygen Depletion

Oxygen depletion in the hypolimnion occurs for two reasons -- respiration by plants, bacteria and animals, and absence of mixing of the water column (combined with respiration). The resultant loss of oxygen plays an important role in regulating the depth regions within which aerobic (requiring oxygen) and anaerobic (oxygen avoiding) organismsi may thrive. The aerobic organisms include some bacteria, most algae, and all animals, and although they may have special adaptations to allow a tolerance to very low levels of dissolved oxygen, even for prolonged periods of time, they must occasionally obtain a supply of oxygen. The algae are the principal source of re-oxygenation by photosynthesis in the metalimnion, and the balance between oxygen production (by photosynthesis) and consumption (by respiration) is critical in determining the oxygen depletion in lakewater. The problem is minimal in surface waters, as the atmosphere overhead is a good source of oxygen.

Fisherman are acutely aware of the oxygen requirement of fish, and know that they can expect no laketrout fishing where oxygen has been depleted in the cool bottom waters of a lake. In fact, the laketrout, as well as related species of fish, are entirely eliminated from such lakes. Even though the surface waters are well oxygenated, the temperature is too high to support the salomind-type fish.

Most people are unaware that important groups of micro-organisms thrive in the anoxic (lacking oxygen, similar to anaerobic) bottom waters of lakes. For the most part, these are the important groups of bacteria that regulate cycles of nutrients at or near the bottom of such lakes. The bacteria are involved in crucial processes that may determine the chemical quality of the lake -- including modification of all nutrients essential to growth of the microscopic algae -- such as carbon, phosphorus nitrogen, and sulphur, by putrefaction or break-down of dead organisms, and by fermentation. The anaerobic bacteria are also involved in processes such as nitrogen fixation that converts unavailable nitrogen to very-available ammonia, and in the formation of a large host of dissolved organic substances such as vitamins that promote the growth of microscopic algae. In general, the anaerobic bacteria can be viewed as the principal agents involved in promoting recycling of essential nutrients that otherwise would have been lost and locked up in the lake sediments.

Water transparency

Water transparency, as indicated by secchi disk depth, is influenced by many factors. Dissolved substances such as humic acids (tea-colored coloring matter from plant decay) will frequently lend a yellow or brown color to the water, thus decreasing its transparency. The humic acids are especially prevalent in waters running through bogs or coniferous forests.

Another factor affecting water transparency is the number of particles suspended in the water column. These particles are of two types: sediments and living organisms. Sediments are especially prevalent in areas where mixing occurs all the way to the bottom, as during overturn of holomictic lakes. Human activity such as boating or swimming can also resuspend sediments. Among living organisms, phytoplankton has the greatest effect on water transparency, due to its pigmentation and abundance. Chlorophyll a, the pigment common to all photosynthetic phytoplankton, is used as one measure of phytoplankton density.

Water transparency (measured as the Secchi Disk Depth), chlorophyll a and thermal stratification, along with other important physical, chemical and biological obsevations of study lakes, are the core of the lay monitoring program. Long- or short-term trends in these data can be used as indicators of changing trophic status of lakes.

Lake Trophic Status

Every classification scheme suffers from over-simplification! The very act of classifying requires the definition of classes within which study objects may be placed or pigeon-holed. Often the classes are defined by some arbitrary means, and the boundaries are subject to change depending upon the definition that is used. The fundamental problem with the process of classification is that once boundaries are set and <u>classes</u> are defined, we tend to think of the <u>classes</u> as somehow isolated from each other. Instead they may blend into each other at the boundaries. As you consider the classification scheme, please think of a continual gradient of individual lake types, through which any lake may pass. The passage may require a long period of time, given changes in the landscape or climate by natural causes, or a relatively short time given human-induced changes in use of the lake or its shoreline and watershed. One may hope that the following five categories of <u>trophic status</u> will help to simplify what we know about lakes, yet leave us with a sense of the probable evolution of lakes between classes of <u>trophic status</u>.

Three major categories of trophic status include <u>oligotrophy</u>, <u>mesotrophy</u>, <u>eutrophy</u>. <u>Oligotrophic</u> lakes characteristically have high <u>transparency</u> and low concentrations of <u>chlorophyll a</u> and phosphorus. Therefore, a large fraction of the visible portion of sunlight radiation, including from blue through red light, can penetrate to great depths in the lakes. <u>Mesotrophic</u> lakes are intermediate, and <u>eutrophic</u> lakes have relatively low <u>transparency</u> and high concentrations of <u>chlorophyll a</u> and phosphorus. Due to the high <u>chlorophyll</u> concentration, restrictions are placed on the transmission of sunlight into <u>eutrophic</u> lakes -- especially on blue and red light that are absorbed in the upper waters of the lakes by microscopic algae. Generally green light penetrates furthest into such lakes, and although it can be used in photosynthesis, it is less efficient than red or blue light. Thus photosynthesis is more restricted to upper layers in eutrophic lakes than in less-productive lakes. .p;Two additional major categories of lakes are dystrophy and mixotrophy. Lakes in these two categories have a high concentration of humic acids, and thus are heavily stained. Light penetration is severely restricted by the tea-colored stain, and only the red portion of sunlight is transmitted beneath the surface. Therefore, microscopic algae can grow only near the surface, and even then are light-limited (little or no blue light is transmitted to them). If such a lake has a low concentration of microscopic algae -- indicated both by algal counts (with a microscope) and by a low chlorophyll a concentration, the lake is called dystrophic. It is probable that the lake has a low input (loading) of nutrients, so that the microscopic algae are limited both by low light level and by low nutrient levels. However, if the lake receives a large loading of fertilizer, supplying an abundance of phosphorus, nitrogen and other essential nutrients, the microscopic algae may form a relatively concentrated community, and thus the chlorophyll a concentration rises. Such a lake is called mixotrophic -- a 'mixture' of organisms produced within the lake with imported organic material (mainly humic substances) from bogs or other sources outside the lake basin.

Plankton

Microscopic organisms found throughout the water column of lakes belong to the plankton, or plankton community. Members of the community are especially adapted for life in the open water where they must be able to resist gravity to stay in suspension, and to capture energy for survival. Important members of the plankton community are all microscopic, and belong to several different groups of bacteria, algae, fungi, and animals. In some cases the organisms spend their entire life in the open water, while in other cases only a fraction of their life (usually early stages, as in some and insects). Students of biology are often attracted to the plankton community because of the immense diversity of organisms and processes that occur within it, because of its relative importance to a body of water, and especially because much about life of larger organisms can be learned from these special plankton organisms.

Interactions between the plankton community and lakewater determine to a very large extent the trophic status of lakes. In addition, a firm foundation is laid for the long-term management of lakes when the characteristics of the plankton community and the lakewater are determined. Seasonal changes in both the planktors (members of the plankton community) and in the water chemistry require that several observations be made each year in a lake. Annual changes are generally slower, and can be discerned only during the course of long-term monitoring of principal parameters of plankton and water chemistry.

It is beyond the scope of this section of the report to describe all of the important changes that occur in the plankton as a lake passes through various trophic stages (oligotrophy, mesotrophy, etc.). But foremost among these is the change in concentration of plankton organisms -- especially the microscopic algae. This change is usually regulated by chemical loading into lakes, but is also regulated by seasonal changes in weather, and by several biological processes that occur in lakes -- such as grazing by microscopic crustaceans (water fleas and their allies). A good monitoring program includes not only an analysis of numbers of plankters, but also of types. Predictions of trophic evolution in lakes may be discerned more quickly by observing such changes in the plankton.

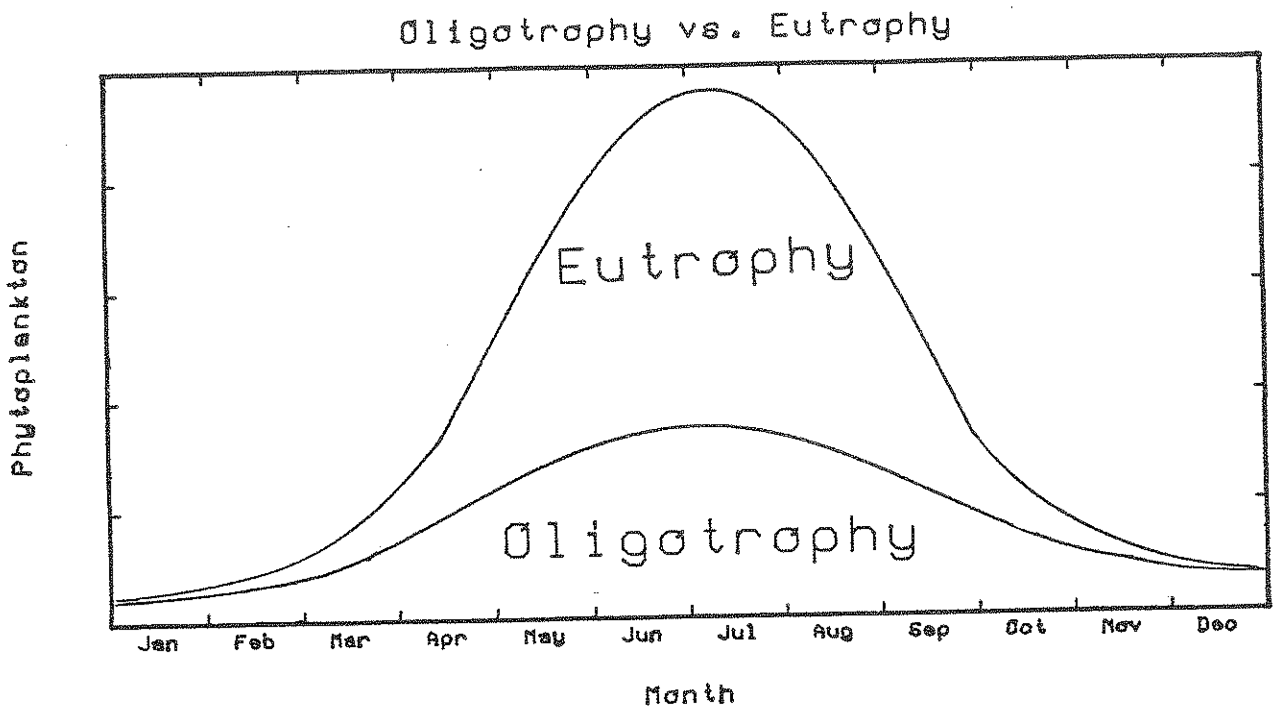

Figure B - 2. Diagrammatic represenatation of the seasonal changes in phytoplankton density. Differences between oligotrophic and eutrophic lakes are emphasized during the summer period. This shows the importance of collecting data throughout the summer, with complete weekly sampling. Note especially the rapid changes in phytoplankton density from month to month. These changes are most pronounced in eutrophic lakes.